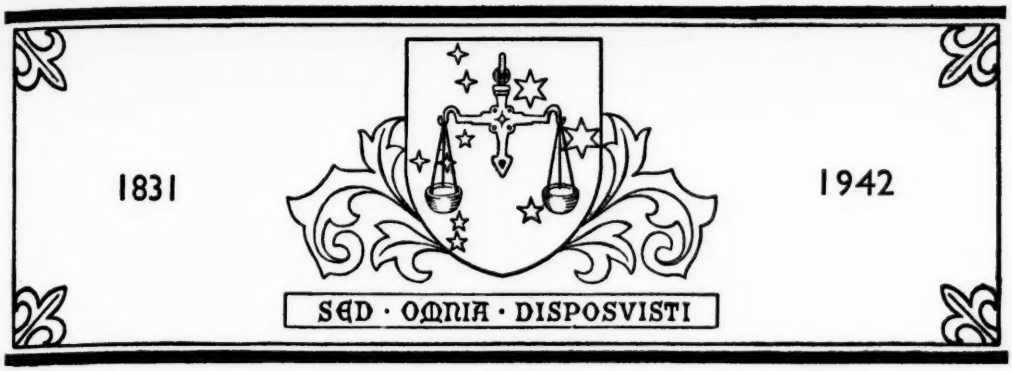

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MINERAL RESOURCES
AND THE ATLANTIC CHARTER

TRANSACTIONS OF A CONFERENCE HELD BY THE DIVISION FOR THE SOCIAL AND INTERNATIONAL RELATIONS OF SCIENCE, JULY 24–25, 1942

The Preamble of the Atlantic Charter :—

The President of the United States and the Prime Minister, Mr. Churchill, representing His Majesty's Government in the United Kingdom, being met together, deem it right to make known certain common principles in the national policies of their respective countries on which they base their hopes for a better future for the world.

The Fourth Clause :—

Fourth, they will endeavour, with due respect for their existing obligations, to further the enjoyment by all States, great or small, victor or vanquished, of access, on equal terms, to the trade and to the raw materials of the world which are needed for their economic prosperity.

INTRODUCTION

AT the Conference on Science and World Order held in September 1941, and reported in *The Advancement of Science*, No. 5 (January 1942), some important aspects of social and international relations of science were presented by representatives of the United Nations. One particular purpose of the Conference was to consider natural and national resources of materials and power to use them from an international point of view. These resources fall into two main groups—agricultural and mineral—which are dependent one upon another for their progressive development. A scheme was outlined at the Conference for the institution of an International Resources Organisation capable of taking a comprehensive view of the world's resources—material, technical and human—and co-ordinating knowledge and action in their use. The Conference on European Agriculture : Scientific Problems in Post-War Reconstruction, held in March last, and reported in *The Advancement of Science*, No. 6 (July 1942), and the Conference on Mineral Resources and the Atlantic Charter, reported in following pages, dealt with the kinds of facts which will have to be considered in all scientific systems of post-war planning.

Modern industrial civilisation depends upon mineral products for its existence and advance. Since geological factors control the distribution and emplacement of mineral deposits, their location bears little relation to ephemeral national boundaries. No country is wholly self-sufficient in the great variety of minerals now thought to be necessary for modern requirements, especially in view of the increasing importance of key alloy metals. The sporadic occurrence of ore-bodies, as exemplified by those of tin, manganese, and nickel, emphasises the interdependence of nations for essential minerals and the need for free access to the sources of supply. It is true that under pre-war arrangements there were facilities for trading and purchasing in world markets, but always under the shadow of arbitrary controls and restrictions and ever hampered by competitive struggles between rival interests. The removal of restraints to the free flow of international trade should lessen the causes of friction between nations and help to promote world harmony.

Systematic international planning of mineral production, distribution, and consumption should become an international objective after the war. Each country should strive to intensify its own achievements in the domain of mineral development and production while yielding to none in its endeavour to foster world-wide co-operation in the exchange of raw materials and finished products. As complete and accurate knowledge as possible is required concerning the distribution and assessment of the world's mineral resources, in order that an effective policy of exploitation and distribution can be formulated for the benefit of all peoples. The compilation of

statistics and the correlation of information should be undertaken in all countries, and the findings submitted to an International Resources Organisation concerned with the proper utilisation of those resources. In this country, for instance, the Mineral Resources Department of the Imperial Institute should receive much greater encouragement and be granted opportunities to increase the scope of its activities. The aim should be to collect and systematise available private and public information concerning the known and potential reserves of all mineral deposits.

There is need for more geologists, geophysicists, and mining engineers to carry out exploration and development throughout the world, and especially in the vast areas never yet surveyed, as in the U.S.S.R. and in China. In both these countries—very notably in the first—the resources of science in this connection are appreciated and are being applied. The present dearth of trained personnel in Britain is much to be regretted, and steps should be taken forthwith to remedy this educational defect. Minerals containing the rarer elements, such as molybdenum, vanadium, beryllium, thorium, and zirconium, are becoming of increasing importance in industry, and ample opportunities exist for their systematic prospecting.

The sea is an inexhaustible reservoir for the recovery of certain mineral raw materials. It has long been a source of common salt, and within recent years the extraction of potassium, magnesium, and bromine salts has been accomplished on an increasingly large scale. With the passage of time and the invention of new chemical devices there is little doubt that other products, such as phosphates, will be won from the sea. To extract these raw materials economically it is essential to have cheap sources of electric power and heat.

The importance of recovering metals from scrap is still far from adequately recognised, although it is true that scrap already provides a substantial proportion of the immediate raw material of metallurgical industry. In future the recovery of scrap is bound to assume a major rôle in the conservation of metal resources. There is an urgent need for the institution of measures ensuring a maximum recovery of scrap, and for the compilation of international statistics relating to the available reserves of scrap metal. Clearly this information should be correlated with data concerning the world resources of unworked mineral deposits, and used in formulating schemes for the best utilisation of our total supplies. Various means of economising metals, including the use of concrete and welding methods and the employment of substitutes, such as plastics, must also be considered in the light of mineral conservation.

The volume of international trade will be affected to no small degree by the extent to which factors favouring the retention of metal industries in already established areas are offset by tendencies which promote the growth of finishing industries in countries producing the raw materials. Naturally the mineral industries must plan their future in relationship to the schemes of other industries, such as the chemical and agricultural.

Many aspects of mining finance, and monetary problems connected with the exploitation of mineral deposits in the colonies and elsewhere, require stringent supervision by a central agency actuated by a desire to beget universal prosperity and not by any motive exclusively based upon considerations of profit. It should be obligatory on all those engaged in or benefiting by mineral exploitation to safeguard social and economic interests during the period of active operations and in the difficult times attending the exhaustion of the deposits.

The United Nations possess immense proved and potential resources, and by curtailing the export of strategic minerals they have the power to prevent would-be aggressor nations from amassing armaments. It may be prudent to exercise this control as a potent instrument in the preservation of peace after the cessation of present hostilities, until the impulse to resort to the madness of war as a means of settling disputes between nations shall have been effectively repressed. The necessity of achieving a just and proper utilisation of our mineral resources is an urgent post-war problem, and if the policy contemplated in the fourth clause of the Atlantic Charter is implemented in a spirit of general goodwill the outlook for mankind promises to be brighter and happier than ever before.

Such are some of the larger considerations developed in communications at the Conference recorded in following pages.

* * * *

The inclusion of the proposal for an International Resources Organisation in the resolution moved by Sir Richard Gregory, Bt., F.R.S., in his capacity as Chairman of the Division for the Social and International Relations of Science, and seconded by Dr. C. H. Desch, F.R.S., related the problems of Mineral Resources to a much wider question. The terms of the resolution will be found on a later page.

It referred back to the parent Conference on Science and World Order, held, as already stated, in September 1941, of which the present Conference was an extension. At

the Royal Institution, a sequence of speakers, dealing with the problems of Human Needs, World Planning, Technological Advances, and Post-War Relief, stressed the need for an international organisation embodying the scientific method and the scientific approach. Prof. J. D. Bernal, F.R.S., in consultation with other speakers, afterwards supplemented his own address, for publication in the report of the Conference, by a concrete plan (see *The Advancement of Science*, No. 5, p. 17).

This plan laid down the requisites for an International Resources Organisation, stressing that this, by the nature of modern advances in science and technology, could not be limited to mineral resources, agricultural or forest products ; it must include the new scientific products which were not geographically or geologically limited ; it must include the processes and scientific personnel by which these materials were made available. The 'I.R.O.' would be concerned with the collection and analysis of data on resources ; the dissemination of information on resources and techniques ; the co-ordination of existing scientific bodies on an international basis ; the initiation of surveys and researches required to bridge existing gaps in knowledge ; the promotion of new industrial and scientific research and development ; the general supervision and co-ordination of standards, specifications and technical codes, bearing upon the development of resources.

The proposal, in essence, was aimed at securing, in terms compatible with the rapid and world-wide developments of the twentieth century, one of the objects for which the British Association was founded—'the removal of any disadvantages of a public kind which impede' the progress of science.

Such an organisation as is proposed would, as the resolution declared, act as a fact-finding and advisory body for governments, as a contribution to world stability. It would provide what has hitherto been lacking—an international clearing-house for information relevant to resources. Therefore, while the Conference on Mineral Resources had been confined to those aspects of Clause 4 of the Atlantic Charter which concerned minerals, it was recognised, in drafting the resolution, that these should be related to the wider considerations of which the proposal for an International Resources Organisation was the expression.

* * * *

The thanks of the Association are due to Dr. David Williams for his help in acting as Recorder at the Conference and in the compilation of these transactions.

Friday, July 24 : Morning Session

Opening by Sir Richard Gregory, Bt., F.R.S., President of the Association

At the meeting of the British Association in South Africa in 1929, Sir Thomas Holland devoted his presidential address to the relationship of minerals to international security. He showed that a new stage of the industrial revolution was reached about fifty years ago and a new mineral era in the world's history was opened. For nearly six thousand years, copper, tin, lead, and zinc, with bronze and brass produced as alloys or mixtures of them were, with iron, the only metals extracted from mineral ores and used in the manufacture of industrial tools and machines as well as for weapons of war. The particular properties of these metals were known and applied by many craftsmen in very early times ; and the steel of the famous Toledo sword blades is not surpassed by steels made to-day by similar working processes.

It was the great British scientist, Michael Faraday, son of a blacksmith, who began the study of the effects of metallic additions to cast steel with the object of obtaining better cutting tools and metals which would not corrode. He made a good nickel-steel and also a chromium-steel similar to the rustless steel discovered nearly a century after his time. Towards the end of the nineteenth century, another Englishman, Sir Robert Hadfield, undertook similar systematic investigations of the effects of various metals in the composition of iron and steel. He discovered that the element manganese, when used in the composition in suitable proportions, produced a remarkably tough steel having high strength and great resistance to abrasion and wear. His production of manganese steel may be said to mark the beginning of the age of special alloys and to have given new significance to the mineral resources of many metallic elements formerly regarded as of purely academic interest.

The chief elements thus used in the production of special steels are chromium, nickel, manganese, tungsten, molybdenum, silicon, vanadium, cobalt, and aluminium. In addition to ferro-alloys, there are also numerous non-ferrous alloys in which such common metals as copper, tin, lead, nickel, zinc, aluminium and magnesium are the main constituents. An unfamiliar metal used in the composition of one of the most important of these alloys is beryllium—an element which was isolated more than a century ago but did not become of industrial importance until about 1925. When from two to three per cent. of beryllium is mixed with copper, an alloy is obtained as hard as steel and with high resistance to corrosion and continual stresses. The metal is extracted

chiefly from the mineral beryl, one variety of which is the valuable gem, emerald. A few years ago the price of a pound of pure beryllium was £100, but improvements in methods of extraction have reduced the cost to about one-tenth and made its industrial uses practicable. Aluminium and magnesium are used in the composition of other non-ferrous alloys on account of their relative lightness. All-metal airplanes are made of an alloy consisting of nine-tenths aluminium with copper, magnesium, manganese and silicon.

Some of these elements in the composition of special alloys required for engineering purposes are widely distributed in the crust of the earth, but no country is self-sufficient in all the minerals from which essential industrial metals are extracted. This is particularly true of metals used in the manufacture of modern weapons of war. Whatever is known of the nature and distribution of common or rare mineral resources and properties of metals derived from them is the result of scientific investigations and their technological applications. The object of this Conference is to present some of these aspects of minerals and metals from scientific, industrial, and economic points of view for consideration in the post-war international policy contemplated in the fourth clause of the Atlantic Charter.

The significance of these relationships was indicated in several papers and other communications at the Conference on ' Science and World Order ' held in London in September last and published by the British Association in the January issue of *The Advancement of Science*. Fuel resources, such as coal and petroleum, will not come under particular consideration at the present Conference, which will be concerned mainly with key metals and their mineral resources. Sir Thomas Holland, who is the leading authority on this subject, has shown how the international control of such resources could relieve the world from the menace of war and secure the maintenance of peace. It is, therefore, with much pleasure that I present him to you to give an address at this opening session. Sir Stafford Cripps will preside at the final session on Saturday afternoon, and the chairmen of the two other sessions will be Sir William Larke, Director of the British Iron and Steel Federation, and Dr. C. H. Desch, Scientific Adviser to the Iron and Steel Research Council.

Address by
Sir Thomas H. Holland, K.C.S.I., K.C.I.E., F.R.S., Chairman

Among the raw materials referred to in the Atlantic Charter minerals form the most important section because of their natural occurrence under fixed geographical conditions which cannot be changed by any artificial measures. They are essential to all technical industries ; and, rightly or wrongly, applied technology has become an inevitable and ineradicable phase of our civilisation. No civilised community can now continue to be active without a sufficient, and sufficiently varied, supply of mineral products ; substitutes for them cannot be provided, except to a very small degree, by other materials, natural or artificial, without some increased cost and with some loss of efficiency. The demand for them is insistent and certainly will increase in the immediate future. The problems before us are therefore urgent.

Yet, the workable deposits of useful minerals are distributed without regard to established national boundaries. It follows, consequently, that, so long as difficulties are created among the nations for the exchange of such raw materials, there must always be potential friction between the ' haves ' and the ' have nots.' One can even go further and say that, whilst tariffs can hamper international trade in mineral products, no tariff or embargo can prevent the trade altogether without the immediate creation of conditions which are certain to lead to war.

To many members of the British Association these unqualified dogmatic statements may seem to be already familiar and even well worn since our South African meeting in 1929 ; they ought to be a redundant reminder to every student of public affairs after the world publicity that was given to the fatuous activity of the League of Nations in 1935, when they kept out of the doses of sanctions to be applied to Italy those minerals which would have made the medicine lethal—copper, petroleum, coal and steel.

A discussion of these questions, however, with a responsible public body just before the present war, left me with the impression that, whilst they were then regarded with polite interest, they were still considered to be little more than matters of academic importance in this country, with its supposed command of the seas, in an Empire approaching self-sufficiency. Some, far too few, observers of international problems have begun gradually, and indeed too slowly, to realise that the configuration of our civilised system has fundamentally changed, and even before the war was then changing with an acceleration too great to be grasped by our public leaders.

In these opening remarks it will not be possible or necessary to do more than present one or two illustrations to remind you of the importance of selecting this section of the Atlantic Charter for our special discussion ; and this limitation of the short time at our disposal to mineral questions does not mean that we fail to recognise the significance of other raw materials.

But it is the speed of change in the international bearing of mineral questions which gives them special urgency. During the first thirty-seven years of this century, for example, the output of ordinary steel in the United States increased five times, from about ten to over fifty million tons, and, to produce the output for 1937, three-fourths of a million tons of manganese-ore had to be imported as one constituent among the accessory raw materials. In the latter year, with the help of a protective tariff amounting to about 100 per cent. of the import price of manganese-ore, the United States did not produce enough of the ore from domestic sources to meet much more than about five per cent. of that country's own essential requirements.[1]

You can guess therefore what the result would be if an extension of the recent tendency towards

[1] In giving these round figures I am not unmindful of the fact that research on methods for concentrating the large deposits of American low-grade ores shows some signs of possible success in times of high prices or during the emergency of war.

nationalism went so far as to prohibit the export of manganese-ore to the United States from the four or five principal sources—the British Empire which then produced one-third of the world's total of six million tons, and Russia which produced another third, both countries, especially Russia, wanting a large share of their own outputs; whilst France, Germany, and Japan, producing between them negligible amounts, wanted most of the remaining third. Short of absolute prohibition, tariffs might conceivably force the United States to exploit more vigorously its own deposits at home and in Cuba, with the result, however, that all known workable high-grade resources of manganese-ore at the disposal of the American Government would be effectively exhausted within a few years.

The world is so made that the chief steel-making countries—the United States, Great Britain, Germany, France, Italy and Japan—have little more than negligible resources of manganese-ore to rely on within their own political boundaries, whilst the countries in which the mineral occurs in greatest abundance are but small consumers of it. During 1937, four-fifths of the world's output of steel occurred in countries which produced only about two per cent. of the required manganese.[1]

India is now producing over a million tons of steel annually, but uses for the purpose less than two per cent. of its own output of manganese-ore. Russia thus becomes an outstanding exception; for many years it has been the world's chief producer and exporter of manganese, and, unexpectedly to others, during the decade before 1937 increased its output of steel ten times, thus passing from the sixth to the third position among the steel-making countries.

Now we can speculate with some degree of certainty on one important reason why Germany suddenly broke her pact and invaded Russia. It was a prospective shortage of manganese rather than of petroleum which threatened disaster to Germany's munition supplies. Petroleum can be made to some degree and to an increasing extent from the abundant brown coal supplies in Germany itself, although this incurs the absorption of much technical man power, and supplementary natural supplies of oil are obtainable from other controlled countries, especially from Rumania.

But of manganese all the European countries under the domination of Germany cannot together produce more than a small fraction of that necessary to feed the steel furnaces under German control. Before the war the countries now under German domination imported annually over 1½ million tons of high-grade manganese-ore. The most productive among them has never turned out a tenth of this quantity, and even that was of a relatively low grade. Before the war of 1914–18 both France and Germany had accumulated some stocks of manganese, but not nearly enough to see them through, and Germany being then hampered at sea, was finally in serious difficulty.

One cannot, however, be quite confident in estimating the stocks of manganese still available in countries now under German control, because, whilst there is evidence that Germany herself was very late in commencing to accumulate stocks of imported ore for emergency use, it is obvious that France began soon after 1922 and continued annually to import more manganese than was necessary for her output of steel.[1]

But this is but one of the many secondary ways in which the French people themselves and their former Allies have been 'let down' by a few of their weak and treacherous political leaders.

Whatever doubt on this account there may be about Germany's present access to reserves of manganese, one can be more certain about her anxiety to exploit some others of the varied mineral resources of the Soviet, and one of these is almost certainly the relatively rare metal platinum, which is wanted in fairly large quantities for various war industries including the manufacture of nitrous explosives.

As a small relief from the depression which one occasionally feels because of the general public ignorance about mineral questions under war conditions, it is encouraging to see that *The Times*[2] noticed this probable shortage of platinum only a fortnight ago, and drew attention to the fact that, although the world output of the precious metal has trebled during the past twenty years, the substantial sources of supply are still under the control of the united democratic nations, Canada producing about half, Russia about one-fifth, America and South Africa between them another fifth, supplemented by smaller quantities from the Republic of Colombia, Belgian Congo and Abyssinia.

The argument which I have used, based on our information about the natural distribution of manganese-ore in the world, is no lonely illustration of the fact that the occurrence of mineral raw materials does not coincide even approximately with the national domains in which technical industries have been most highly developed. There are others of a similar type on which the continuance of present civilised activities are dependent, and the American Government, wisely listening to its scientific and technical advisers, have labelled a dozen such minerals, on this account, as 'strategic,' that is, minerals on which the States depend on outside—sometimes distant—sources, for those supplies which are absolutely necessary to maintain their essential industries and therefore to ensure their safety in defence.

Manganese came into general use soon after the invention of the Bessemer process in the middle of the last century, and well over 90 per cent. of the metal produced in the world is still consumed in steel-smelting. Although the metal is thus consumed only in a way analogous to that of a medicine, there is no known substitute to take its place on a large scale, and so under present war conditions it becomes a 'key' product.

But out of the study of its function in this way there arose some twenty-five years later a quite different use for the metal as a definite constituent of the manganese-steel which was invented by

[1] G. A. Roush, *Strategic Mineral Supplies*, McGraw-Hill, 1939, p. 38.

[1] G. A. Roush, *op. cit.*, p. 68.
[2] July 8, 1942.

one of our distinguished members, the late Sir Robert Hadfield. And his invention of manganese-steel opened up a new era in metallurgy, for it became the forerunner of a whole family of alloys of iron with relatively rare elements like cobalt, chromium, molybdenum, nickel and tungsten.

It was the discovery and extended use of these new alloys which changed, and changed on a large scale, the problem of supplies for the industrialised Great Powers. In the last century mechanical industries sprang up around areas containing deposits of the small number of natural products required in the manufacture of ordinary iron and steel ; for example, around the British coalfields, in which there occurred associated supplies of iron-ore, limestone-flux and coking coal. When the local supplies of ore became relatively exhausted, improved transport facilities enabled Great Britain to bring iron-ore from Spain and Scandinavia. But then again, when ferro-alloys, with their very special and previously unexpected properties, superseded ordinary steel, their constituents had to be brought from still more distant parts of the earth, and the whole problem of commercial success in industry, as well as security in war, thus assumed an entirely new configuration. For, in addition to the family of ferro-alloys, other alloys of industrial importance were discovered, such as those largely made of aluminium and magnesium combining low density with sufficient strength for aircraft and bridge construction. Nor indeed is the end of this avenue of metallurgical development in sight or even predictable.

A country like Great Britain which was practically self-contained for the few and simple essential constituents of ordinary steel up to the last quarter of the nineteenth century, quickly found itself dependent on supplies from distant parts of the Empire, and even from foreign competitors. From the happy condition of congratulating itself—even occasionally giving some credit to Providence—the new century found Great Britain, for example, looking to Canada and the Belgian Congo for cobalt, to British Guiana and France for aluminium-ore, to Canada for nickel, to India and the Gold Coast for manganese, to China and Burma for tungsten. A new meaning was given to the importance of retaining command of the seas, which seems now to be giving place to command of the air.

These are but a few among many mineral products which are just as essential as imported food for our continued existence as a nation ; and indeed more so, because no artificial effort can grow minerals where they have not been placed already by Nature. There are not and never will be available synthetic metals for industrial use. We can spend a pound note, as we are ordered to do just now, in recovering ten shillings worth of garden railings ; we can use plastic products for door knobs and ash trays to economise imported copper and zinc for brass, but we cannot economically replace bauxite, which we must import for its aluminium, by aluminous clay which we have in abundance ; and generally, whilst one metal can occasionally be used to replace another at greater cost and reduced efficiency, so far as Great Britain is concerned, we cannot produce even inefficient substitutes. But Great Britain is not unique in this respect ; France, Germany, Italy and Japan, as independent units, are also dependent on the outside world in other ways and to different degrees. Even the United States can never be self-contained. Nor can any country derive comfort and security from its greater approach to self-sufficiency ; for what is the use of being able to build a motor car if we are still dependent on another country for a sparking-plug ?

So far I have spoken of essential minerals in qualitative terms. When we consider the situation quantitatively the problem takes a much more serious aspect. The extension of our demands in kind is being accompanied rapidly by a correspondingly increased consumption in quantity, with one immediate and dangerous result that smaller deposits of useful minerals must be neglected for richer and larger masses which can be exploited in bulk. The pace in consumption has increased since 1900 on a scale which has resulted in a greater output than the total production of all previous history back to the Bronze Age.

This comprehensive statement has been met I know with the criticism that statistical records do not extend back beyond the nineteenth century ; but its accuracy can be checked by a simple diagram for any representative mineral used in the industrial arts and therefore can be applied to the whole. We might for example take a metal like copper as one which is familiar to everyone by its widespread use in a variety of ways. At the beginning of the nineteenth century the world produced about 10,000 tons of copper per annum ; by the middle of the century about 40,000 tons, and before the century finished production had reached half a million tons annually. The curve of production went on rising, with only two serious setbacks till it indicated in 1937 that the world's annual output had passed two million tons. Any schoolboy who is familiar with graphs can tell you at a glance that the area of the curve enclosed between 1900 and 1937 must necessarily exceed that of all previous periods since prehistoric man became a practical metallurgist. Similar curves, not always rising so steeply, tell the same story for other familiar metals.

This matter is not mentioned as a mere curiosity of industrial history ; it is to show that, with the growth of national exclusiveness in recent years, there has sprung up an increased interdependence among the nations and especially among the greater Powers, beyond the control and, one can say with safety, beyond the mental comprehension of those politicians who have had most to say, and too much influence, on the international questions which have brought us to the present condition of universal war.

As one result of vague fears of aggressive trespass during the past twenty years and in spite of sporadic attempts to the contrary, the nations have become more and more self-conscious, and, with regard to their natural possessions of minerals, more and more inclined to conserve their resources. Many of them, the British Empire no less than others, have refused the grant to other nationals of concessions to prospect for or to

exploit mineral deposits, thinking through vague fear that some vital asset may thus be squandered, forgetting, however, that a mineral deposit cannot in an emergency be readily turned to account by the nation itself unless it is already developed; overlooking the fact that, even under war conditions, a mine cannot be taken out of the country in which it lies; and failing to realise that what really matters is not the nationality of the *mining* company who risk their money in prospecting and mining, but in which country the mineral is finally prepared for use in the Arts—the Arts of Peace or the Arts of War.

Closing the door to foreign prospectors and miners merely results in bad blood and retaliative measures; it was this policy which tended to keep the United States and the British Empire too long at arms' length.[1] This policy is very different from charging a reasonable royalty and imposing a tariff on the export of raw mineral products as an encouragement to the development of refining operations within the country where mining operations are carried on.

Failure generally to appreciate the fact that our established form of civilisation cannot go on at all without the international exchange of minerals has developed at times a general atmosphere of tension that cannot be relieved except by war. As no country can ever be self-contained in future for essential mineral raw materials, no nation can contribute its share to the progress of our civilisation without the operation of principles such as those outlined in the Atlantic Charter.

But, for democratic nations to implement those principles, it is necessary for the public to understand far more than they do now the part which mineral problems play in civilised activities. That, I believe, is what the Council had in mind when they decided to devote this meeting to the discussion of mineral questions. We cannot hope, however, in two days to get much further than outline the principal problems which face us when we contemplate measures to facilitate the international flow of such raw products.

In the United States the problems have been examined in critical detail for several years by selected Committees of technological specialists, but naturally their chief object has been to provide military security for their own nation in a world threatened by potential aggressors.

The Soviet Republics of Russia have done the same by official organisations, and most other nations of the world seem so far to have failed to appreciate the extent of their resources or the realistic thoroughness which has actuated the present Government of Russia in the utilisation of applied technology.

Fifteen years ago the British Empire Council of Mining and Metallurgical Engineers formulated proposals for a similar investigation of our scattered resources, but the Dominion governments have apparently been distracted by the immediate problems of promoting inter-Empire commerce, and have consequently overlooked the dangers of national exclusiveness regarding mineral raw materials, which all well-behaved nations must reasonably obtain if civilisation, such as we know it, is to survive.

At the time of our South African meeting I could see no further than a possible understanding—which is the first necessary step towards agreement—between the United States and the British Commonwealth who between them, at the time, controlled three-fourths of the world's workable deposits. My imagination takes me in the same direction still, but very little further along the road towards the development of an international conscience about the hoarding of mineral deposits.

Let us hope that this discussion will result in inspiring another serious effort to formulate measures for facilitating as well as controlling the international flow of mineral products, keeping always in mind the simple circumstances that no country is or will be self-contained for mineral supplies, and no development of science can or ever will grow workable mineral deposits where they are not already formed by Nature. And I ought perhaps to repeat what I suggested at the beginning of my remarks, that this question is by no means a matter of academic interest. It is one that must be settled and settled quickly by practical measures if civilisation is to be saved for our descendants. Unless it is settled, and settled quickly at the end of the war, by an intelligent understanding among the successful powers, newly concocted aggressive attempts to enforce control will lead intermittently to further outbreaks of war. Delay for more mature consideration may be the very rashest step for us to take.

[1] *Elements of a National Mineral Policy, prepared by The Mineral Inquiry of the American Institute of Mining and Metallurgical Engineers* (New York, 1933), pp. 6 and 7.

Prof. H. H. Read, F.R.S.

The Geological Control of Mineral Deposits

Introduction.—Before certain special and topical mineral deposits are considered, it is necessary to put certain generalities before you, and that is my present purpose. I have to give an outline of geological history with special reference to the subject of this conference. I ask pardon of you, Sir Thomas, and of the hosts of eminent geologists I see about me, if I deal with this matter in a very elementary way—I am really speaking to the few modest people in this gathering who profess to little geological knowledge and also possibly to a few future planners who have strayed in.

There is, as has been reiterated lately in several quarters, a general unawareness of geology among what I may be forgiven for calling the governing classes of this country. I could cite examples of gross waste of public money through this unawareness, which is the result, fundamentally, of the lopsidedness of both our general and scientific education. This unawareness is seen too in countries other than our own, as shown by the impossible demands for autarky by dictators ignorant of their countries' geology. An autarky based, like the Russian, upon a proper estimation of mineral resources is one thing, and an autarky by legislation another. An infant mineral industry cannot be developed if geological conditions are against it, and attempts at the development of mineral deposits not worthy of development are a weariness of the flesh.

It is not yet universally realised that geological history controls the distribution of minerals, and that this history is fantastically varied in space and

time. We are used to the shop notices ' No cigarettes,' ' No matches,' ' No sweets '—it would be well if countries put out notices, such as ' No coal,' ' No oil,' ' No iron-ore.' Perhaps if these notices were as large as Ireland, they might catch the planner's eye. The North Atlantic countries are not really populated by people specially virtuous, or specially noble, industrious, or gifted, or even specially acquisitive—they simply happen to be countries which had a geological history favourable to the formation of mineral deposits, and upon these lucky foundations has been built their industrial structure.

The Crust of the Earth.—We have a record in the rocks which make up the crust of a history of over two thousand million years. But even in this gigantic stretch of time no geological event repeats itself exactly—a diversity is at once implied. And greater diversities in the distribution and character of rocks are implicit too in their manner of formation.

The sedimentary rocks, such as the ordinary sandstones, clays and limestones, were mostly deposited in shallow seas subject to wave and current fluctuations, and were deposited over restricted portions of these seas. At one and the same time there may have been laid down in one area a deltaic or shore deposit which passed one way into a shallow-water sand and another way into a clear-water limestone—all rocks of the same age but very different in character. Further, over the land areas of this time other types of sediments were being formed in widely varying environments—desert, lacustrine, fluviatile, glacial, and so forth. Infinite possibilities exist therefore for original diversities in the characters of the sedimentary rocks laid down at one particular time, for rapid variation in such deposits from place to place, and, since no event repeats itself, for innumerable differences between the deposits of different times. Unending complexities are to be expected amongst the sedimentary rocks.

The second great group of rocks, the igneous rocks, results from the solidification of lava or from rather more mysterious and deeper-seated processes within the crust. However the liquid rock material is produced, it may be moved into different levels of the crust, reacting differently with the varied rocks it meets in its passage, taking material from one and giving material to another, and becoming modified in many other ways. It may finally solidify in very diverse environments, it may freeze quickly or slowly, its gases may be kept in by pressure or may escape to cause great changes in the adjacent solid rocks. It may form small rock masses with dimensions to be measured in centimetres or, as in the Bushveld of S. Africa, one igneous rock body may be as large as Scotland. In igneous rocks, too, there arises a gigantic series of variations and diversities in character, size, age and history. Many of the ore-deposits we shall be hearing about later are genetically related to igneous rocks.

The third great group of rocks is produced from the sediments and the igneous rocks by changes in pressure and temperature—these are changed or metamorphic rocks. When we consider the immense variety of the starting materials and the innumerable combinations of different pressures and temperatures of their metamorphism, we will realise once more the remote chance there is that any two metamorphic rocks are exactly alike.

Geological history, however, is not simply a record of rock deposition, of solidification or of metamorphism. At periodic intervals violent revolutions take place in restricted belts of the crust. Immense piles of sediments, which had been built up in quiet seas for millions of years, are violently folded into mountain ranges. Instead of the seas of Tethys, for example, there arose the great fold belts of the Alps and Himalayas. Marine sediments form land masses and the continents become more extensive. So soon, however, as the land masses are formed, they are acted upon by the agents of erosion, the wind, rain, frost, rivers and so on, and their material is carted back to the seas again. On the original diversities, therefore, there are superposed diversities arising from the restricted and periodic mountain-building movements and from the unequal removal of land masses back to the sea—diversity upon diversity.

When I contemplate the products of geological history, I am amazed at the courage of the geologist who, usually credited with possessing solely a good pair of legs and a good wind, stands calm and undismayed in the midst of so many and great complexities. No wonder geologists often become highly successful Principals and Vice-Chancellors of Universities !

The Average Rocks of the Crust.—A more or less reliable estimate can be made of the composition of the crust. Eight elements make up 98·6 per cent. of the crust, these elements being: Oxygen, Silicon, Aluminium, Iron, Calcium, Sodium, Potassium, Magnesium. Of these, only Aluminium, Iron and Magnesium are of major economic importance—all the other economic metals, such as copper, lead, zinc, tin and so forth, are present in amounts of less than $\frac{1}{100}$ of 1 per cent. These estimates deal with percentages of metals in the rocks of the crust. The metals in the deposits of useful minerals must therefore be only a minute fraction of the quantity of metals in the crust—this fraction having been locally accumulated by some *process of concentration.*

The Formation of Mineral Deposits.—The chief processes of concentration of minute amounts to form mineral deposits of economic importance are given by Lindgren as follows :

1. Fractional crystallisation in the liquid rock material of the igneous rocks : examples, magnetite, chromite, platinum deposits.

2. Silica-rich extraction from the liquid rock material leading to concentrations as, for example, of tin and tungsten in pegmatite dykes and quartz veins.

3. Action of gas-fluxing components, reaching still farther from the cooling igneous rock, and giving rise to the large proportion of metalliferous deposits.

4. Concentration by solvent action of underground waters, e.g. deposits of iron, copper and lead.

5. Concentration by surface waters, sometimes

leading to the enrichment of low-grade deposits, or the formation of rich residual deposits.

6. Concentration by sedimentation. Mechanical sorting during formation of the sedimentary rocks leads to deposits of heavy minerals such as in gold placers. Another type of concentration leads to deposition of beds of salts and other vital industrial minerals.

7. Concentration by biochemical processes—formation of coal, petroleum, phosphate, etc.

Again Diversity.—These processes of concentration are varied ; they are subject to chances and hazards, so that again the degree of diversity of the crust is increased. From the nature of the factors governing the formation of any mineral deposit, it is evident that mineral deposits must be very unevenly distributed in the earth's crust. National boundaries have in general paid little attention to the more complex of the geological boundaries ; hence there are ' have ' and ' have-not ' countries, as will be demonstrated by later speakers.

Conclusion.—From these remarks it is clear that we have to accept the geological make-up of the crust, we have to realise that nothing can be done to change that make-up, and that, therefore, mineral resources cannot be created by edict, command, legislation or wishful thinking. A change in mineral distribution is not within our power, and since not even a combination such as the United Nations would be self-sufficient, Clause IV of the Atlantic Charter is relevant.

Prof. C. B. Fawcett

Key Metals and the Location of Industry

FROM the beginnings of man's knowledge of metals up to about two hundred years ago the number of known metals could be counted on his fingers. There were the ' noble,' but not particularly useful, gold and silver ; and such ' base ' metals as copper, iron, tin and lead, which made up for their baseness by being useful. Mercury also has long been known. And bronze and brass were known ; though it is doubtful whether their composition and their relations to copper, tin, zinc and antimony were understood before the eighteenth and nineteenth centuries.

Such was the stock of metals known and used—in small quantities—before the dawn of Science. The number now known and used is at least five times as great. But, except for aluminium, the newer metals are, for the most part, available only in relatively small quantities, and they are chiefly of importance for their part in the formation of many alloys with the older metals. Iron is by far the most important base of such alloys, and it is still the most important of all the metals.

The effects on human society of so great an addition to available natural resources are both complex and far-reaching. They amount to a new industrial revolution. But here I wish to note the results of some inquiry into the effects of the use of some of the new metals on the location of industry, which is an important fact in the economic and social organisation of a modern civilised community.

These key metals are used chiefly in forming, with iron, most of the many steels which are now known and used. Up to a century ago the only important steel was carbon steel, which had been known to some extent for perhaps 2,000 years. But though it was known, in the sense that it could be produced by the smelting of some forms of iron with some forms of charcoal, that knowledge was only empirical ; and it was not known in the sense of being understood sufficiently to enable us to control its composition and properties. So that before the middle of the nineteenth century the making of steel on any large scale was still something of a gamble. The process could not be understood—and so controlled—until the sciences of chemistry and metallurgy had made considerable progress. Then came the systematic study of iron and steel. This led to a knowledge of the solvent powers of molten iron ; and so to a study of the properties of the solidified solutions—the steels. Such investigation demanded large-scale organised research, and most of it dates only from the present century, particularly during and after the war of 1914–18, even though, as the President has reminded us, it was begun by Faraday. Not all of the steels are of present importance. But some of them are so much so that they have caused a revolution in tool materials. There are now steels which are respectively harder, tougher, less corrodible, more resistant to softening at high temperature, etc., etc., and so more efficient for particular purposes, than any formerly known. We have now better cutting steels than before, and others better for other purposes.

It is probably true to say that the sudden improvement in our chief tool material within this century is a change comparable to that from the ages of stone to the ages of bronze and of iron. And its social effects are likely to be not less than those of the first introduction of metals as tool materials.

The more important of these key metals include chromium, cobalt, manganese, molybdenum, nickel, tungsten and vanadium—a list which is far from being exhaustive.

In relation to the location of industry, and their effects on it, it may be noted that these metals normally occur in quantities which are small in comparison to the ore bodies of the longer known iron and copper, and that they are found in widely scattered and generally small areas, chiefly in rocks of Archean types ; and so in areas away from the fertile lands of dense agricultural settlement and also away from the great coal deposits, which are not found in rocks older than the carboniferous. So the sources of the key metals are, for the most part, in remote and thinly populated lands away from the established industrial areas.

Secondly, the key metals are used in small quantities. Except for nickel very few of them form as much as 10 per cent. of a steel, and usually much less. So that where iron is needed in thousands or millions of tons the key metal is needed only in tens or thousands of tons.

Thirdly, in its relation to industry it is characteristic that the whole of a key metal used becomes part of the final product. The amount wasted in the process of manufacture is negligibly small, partly because the high cost leads to greater care in its use.

Many of these metals are found in such a form

that the metal itself is only a small proportion of the material mined ; down to 5 per cent. or even less. Hence there is usually a process of ' concentration ' at, or very near to, the mine. The location of the mine itself, and of this ' concentration,' is of course determined by the place of occurrence of the ores. But once the concentrate, or ' matte,' is obtained it is transported to existing centres of industry to be refined and then used. And it seems that the place of occurrence of the ores of the key metal has, in most cases, little or no influence on the location of the industry which uses it.

Let us consider, very briefly, some factors influencing the location of manufacturing industry, and their relation to these metals. Such factors may be grouped as primarily economic, or social, or political : though some may come under more than one of these heads.

The *economic* factors are chiefly those concerned with the needs for transport and power. In respect to the first the materials to be used can be divided into (*a*) those which are wholly or mainly used up in the processes of manufacture, and (*b*) those which, like the key metals, form part of the finished product. The latter must, in all cases, be transported from their place of origin to the final user of the product ; and usually it makes little difference to the final costs where they are stopped on this journey to undergo the transformation from raw materials to finished goods. There is, however, a difference according to whether the user is widespread or concentrated. And in the case of the key metals it is mostly the latter ; for the alloys of which they are parts are built into tools most of which are used in industry (or armaments) and not spread widely in small lots. So there is, in general, an attraction of these materials to the regions of heavy industry, whose location has been previously determined by facts independent of these key metals.

The other chief economic factor is the cost of the power required in the manufacture ; though this, especially when it is in form of coal, might be classed as a ' material which is wholly used up in the processes of manufacture.' There is thus a great saving in reducing the transport of such power. This was the attraction which, in the palæotechnic period, brought heavy industries to the coalfields ; and it is still important, though the more recent electrical transmission of power has lessened the pull of the coalfields.

The chief *social* factors in the location of an industry are related to the amount and kind of the labour it needs. In this respect the key metals are easily classed. They are almost wholly used in industries, and sections of industries, which are dependent on highly skilled labour. Hence the key metals come almost exclusively to regions of highly developed—and so generally of long-standing—metal industries. And by aiding the development of, and the demand for, skilled work, they tend to confirm the existing location of those industries. Up to the present, except for some government armament industries as in Japan, practically all the key metals are used in the two great zones of established manufacturing industries in eastern North America and in Britain and Europe.

The *political* factors are very different in their effects. Here the dominant fact is that the key metals are essential to the armaments industry and to the making of tools which produce armaments. In a world of independent sovran states no state can feel itself secure or really independent unless it has within its borders a considerable armaments industry. In fact no state which is not an important industrial power can, to-day, be an important political power. Thus the political influences on the location of industries are particularly obtrusive in relation to those in which the key metals are vital. In recent years such political influences have been of primary importance in some countries—notably in Germany. And they will be of no less importance after this war. If we are to have a world at peace it will be necessary to control the distribution of these metals through some world organisation.

The economic and social factors favouring the location of industries which use the key metals in the regions of older metal-working industries are further strengthened by the tendency—very prominent in steel-making—to an increasing use of ' scrap metal ' as ' raw material.' [1] This has long been practised with the more expensive metals. Recently ' scrap ' has been used to form more than half the finished steel.[2] Such use of ' scrap ' will be still more widespread if we can attain to a sanely conservative use of our metal resources. In that case we would regard the world's stock of a metal as a ' revolving stock,' to be used over and over again and only replenished with ' new ' metal to the extent needed to make good unavoidable losses by wear and corrosion and accident, and to provide for new uses.

' Scrap ' is already a substantial part of the immediate raw material of these industries. But scrap is produced where metal goods are made and used ; so that this part of the ' raw material ' comes back from the markets. Thus it tends to increase the ' pull of the market ' on the location of the industry, and so to strengthen the forces which keep it within the regions of established industries.

The increase in the number of different materials needed by an industry necessarily lessens the relative importance of each one of these materials in determining the location of the industry—the dependence is on a wider range of natural resources, drawn from more widely scattered areas. And the key metals come in, in relatively small quantities from widely differing areas, to the already established regions of metallurgical industries.

So I conclude that the key metals, as such, have exerted no important influence on the present location of industry. They are fitted into the existing industries, whose location has been determined by a complex of factors ; and they add to the complexity.

They also add to the variety of the materials needed, and so to the range and width of distribution of the natural resources required. Thus they still further emphasise the impossibility of com-

[1] Cf. paper to this Conference by Sir Harold Hartley (see p. 231).

[2] A note in the *Monthly Labour Review* of May 1935 states that in the U.S.A., ' scrap iron and steel ' formed 9·9 per cent. of all the material used in steel-making, and approximately half of that of the finished steel.

plete self-sufficiency for any country, or similar region of the earth, and so the interdependence of all the world's regions.

Prof. P. G. H. Boswell, O.B.E., F.R.S.
Some General Geological Reflections

MUCH private thought has doubtless been given to the terms of the Atlantic Charter, and geologists in particular will have been asking themselves what preparatory work they could undertake in order to implement the Fourth Clause of the Charter. Detailed discussion of the location of useful minerals can safely be left in the competent hands of my geological friends ; for my own part I shall content myself with such general reflections as I have been able to indite at short notice.

The terms of the Charter are none too explicit, perhaps inevitably so. The problems which will arise in the politico-economic field when efforts are made to implement Clause IV are bound to bristle with difficulties. Many of these problems are hardly appropriate to the present Conference ; others, it has been laid down, need not come prominently under consideration here and now. In any case, they are no part of our concern and must be left to the appropriate experts. In order that the discussion of mineral resources should not be entirely academic, however, there are certain geological questions that should be considered if we are to be in any way prepared for action when the time comes.

Firstly, in the matter of assessing the world's resources of essential minerals. All will agree that knowledge of location and quantities available is an essential preliminary, and in this respect our information dates from pre-war days. The very character of the present world-wide conflict, however, has necessitated the exploitation of mineral deposits on a huge scale and may well prove to have permanently changed the relative importance of certain supplies and the location of industries ; also, the requirements for post-war reconstruction are likely to be of such magnitude that the process will be continued. Re-assessment is thus necessary, but can only be effectively undertaken after the war, when conditions once more allow of access and exploration.

Nevertheless, we can proceed to make good use of the data that are at present available. Our sources of information include (*a*) publications of the Imperial Institute (mainly statistical, and relating to production, exports and imports of various countries), (*b*) world conspectuses of the occurrence of individual minerals (such as coal, copper, gold, iron and pyrites) prepared by the International Geological Congress from time to time, (*c*) publications of various official Geological Surveys (such as the mineral reviews of the U.S.A. and the quinquennial reports of the Geological Survey of India), and (*d*) various reference books, such as Mineral Industry, the volumes by Leith and by Roush, and papers published by scientific and technical societies. Many of these publications contain compilations from returns issued by different countries, and considerations of strategy and propaganda render some of the figures suspect. For example, who would trust the returns from Nazi Germany in the pre-war years ? In addition to the lack of uniformity in the manner of assembling the data, a further difficulty arises in the case of statements of available resources, namely, the differing connotation of the expression ' estimated resources.' It is often almost impossible to discover to what extent the statement refers to ' proved reserves ' or to ' unproved but probable ' ; and the propaganda value of liberal estimates has not always been overlooked. In this connection, the Institution of Mining and Metallurgy has for many years endeavoured to secure uniformity of practice and clarity of language in reference to such reserves. Further, as one of the distinguished members of the Institution, Mr. H. Kilburn Scott, has insistently pointed out, available reserves, especially of bedded deposits, should refer to the quantities recoverable and not to those present, a large proportion of which often cannot be extracted.

Statistics inevitably become out of date with the lapse of time, but much of the published information about the mode of occurrence of minerals and the potentialities of the various fields will undoubtedly serve as a reliable foundation for subsequent work. Much sorting-out and collation of details will be required and revision of data will follow, but the task is laborious rather than difficult. Moreover, much valuable information about known resources and estimated reserves is locked away in the archives of mining companies or remains in the possession of mining engineers. At the moment we cannot tell to what extent such confidential matter will be made available.[1]

Scientists, especially those not actively engaged in the war effort, could get to work at once on these preliminary compilations, but I believe that the complete data which should serve as a guide for post-war planning can only be assembled by an International Commission after the war. Such a body could do good work in the meantime if it were suitably financed, but as General Treasurer I do not feel that the financial responsibility can be undertaken by the British Association.

Compilations of the kind just mentioned are doubly necessary, firstly, for the reason indicated above, that political action can be effective only if it is based on knowledge of the location and magnitude of natural resources ; and secondly, because mineral supplies are wasting assets. Therefore, policy must be framed on the reasonable expectation of life. Our chemical colleagues are already providing us with substitutes for many raw materials, and they (and metallurgists) would doubtless find it of advantage to be told what mineral substances were likely to be in short supply : they might then direct their energies into the most profitable channels. As other contributors will probably deal with metals of which the relatively small proved resources give us cause for anxiety, I need not refer to them, but I may be allowed to call attention to the problem of one non-metallic product, phosphate, which occurs

[1] In this connection, see the recently published Presidential Address by Mr. J. Allen Howe to the Institution of Mining and Metallurgy, 1942, on the ' salvage of data ' and other matters relevant to this discussion, such as monopolies, rationalisation, and the review of Empire mineral resources.

but rarely in workable quantities. Yet we continue to waste it prodigally in spite of repeated warnings. To refer to but one reaction, are the world's agricultural needs of phosphate to be satisfied eventually by salvage (on land or from the ocean), or from the only large supplies recently discovered, those of the U.S.S.R.?

In certain cases a particular mineral has been discovered in workable quantities so rarely that the establishment of a monopoly or quasi-monopoly has become possible. If the terms of the Atlantic Charter are to be fulfilled, the continuance of such a state of affairs may call for consideration, although one should in fairness say that in the past monopolies have not always operated harshly. We are here brought up against those political problems which are inappropriate to this Conference, but it will do no harm if we are induced privately to ponder over questions of ways and means in the exploitation of minerals—licensed working, compulsory purchase, the cartel-system, international policing and sanctions, among others.

Investigation of mineral resources should have the twofold aim of discovering new supplies and of maintaining, so far as possible, the activities of existing undertakings. Obviously, exploration must be kept ahead of exploitation. The information presented to this Conference shows—or will show—that large portions of the earth's surface have already been surveyed, often thoroughly so far as common minerals are concerned, but less intensively in the case of rare elements. However, there are considerable areas of which our knowledge is scanty. A decade or two ago, we should have said that the outstanding examples were the U.S.S.R. and China, occupying one-sixth and one-ninth respectively of the earth's land surface. The U.S.S.R., fully alive to the importance of the task, has built up a geological survey with a staff now said to number 10,000 (as compared to staffs numbered in hundreds or less in other countries). As a result, although much remains to be done, knowledge of the mineral resources of the U.S.S.R. has increased enormously; indeed, that State may prove to be the most nearly self-supporting political unit in the world as regards essential minerals. I am inclined to think that one of the most abiding impressions that we shall carry away from this Conference is a realisation of the immense potentialities of the Soviet Union. China, however, still affords vast fields for exploration and, although some of its useful minerals are being exploited, many more are doubtless latent. Smaller areas of the earth's surface are also incompletely explored; others, especially those blanketed by superficial deposits, may yield their secrets to the combined efforts of geologists and geophysicists.

In order that these areas may be examined and their resources developed, geologists and mining engineers will be needed in considerable numbers. As Britain was the cradle of modern geology, and as her sons have long been in the habit of penetrating the unknown in all parts of the world, it is but fitting that we should be prepared to carry on the tradition. Small countries like Britain, Holland and Switzerland have long exported geologists (and imported their earnings), especially since the limited mineral resources at home provided few careers for them. Latterly larger countries such as the U.S.A., the Dominions and Germany have followed suit. To make comparisons, invidious or otherwise, is far from my intentions, but I may express my belief that the powers of resistance, adaptability, field-sense and sound training of British geologists fit them peculiarly well for this pioneer work. But of late years we have been faced by an increasing shortage of geologists in this country largely because of public unawareness of the importance of the subject and its consequent neglect in our educational system. After the last great war, although there had been no pre-war insufficiency, as now, we experienced an acute shortage of trained men. I venture to issue the warning that, after the present conflict, which has diverted many geologists into other fields of activity and denuded the Universities of students in training, the deficiency will be still more serious. Other European countries are not likely to be able materially to relieve the situation; indeed, a number of them were importers of British geologists before the war. We should regard it as deplorable if we could not play our part in the active exploration that post-war conditions will necessitate, and we may therefore insist that it would be a wise move in national policy to begin training geologists without delay. It used to be said that trade follows the flag, but for many years past it has been evident that trade follows the hammer and a nation's goods its mining engineers. To revert to China, for example, we remember with pride that Chinese geologists, in the Universities and in the Geological Survey (from its distinguished Director, Dr. Ting, down through his staff) have been trained in British Universities. It will be unfortunate if such a valuable link in the chain of co-operation does not lead to the forging of others in the future.

Although it might at first sight seem that I had strayed from the murky avenues of international problems into the still more dangerous paths of national interests and aspirations, I feel that, even if I had done so, I could plead justification. And for the reason that, for many years to come, our University staffs and our technicians must continue to take a prominent part in assisting other nationals to develop their own resources and in training them to be self-supporting. We have in this country the brains, exceptional experience and facilities for carrying on the work; it would be regrettable if such advantages were not fully utilised, especially as the results already achieved could be appreciably amplified with the help of a little more encouragement from the State. We ought not to forget that our accumulated knowledge and experience is one of our national resources—and not the least valuable of them. And it may be regarded as an exportable product, to which a lend-lease policy, aimed at facilitating the training of overseas students, could be usefully applied. To put it at its lowest, it would be a first-class investment.

Discussion

Prof. D. H. Peacock, I.E.S.

I SHOULD like to support Prof. P. G. H. Boswell's plea for an increase in the number of geologists

employed in the British Commonwealth. In Burma, of which I have some experience, the Geological Survey working party consists of only two or three members ; the area to be surveyed is nearly a quarter of a million square miles, larger than the German Empire, and much of it is rich in mineral wealth. The number of geologists available is obviously very inadequate. Similar conditions obtain in India, but of that country our chairman, this morning, can speak with greater authority. It is true that in Burma there are a number of geologists working for private firms, but the information which they collect is not available for publication and public use.

The British Government has no control over the number of geologists employed by the Dominions, India and Burma, but it still has the power greatly to expand the Colonial Geological Survey and, in view of the great interests involved, such an expansion is both desirable and economical. The return would certainly justify the expenditure involved.

Dr. J. V. Harrison

PROF. BOSWELL has emphasised that foi the future welfare of mankind information and statistics regarding the world's mineral resources must logically precede any concerted rationing of them which the need for security may make expedient. He has pointed out that the sources from which this information must come are disperse and sometimes difficult of access. Some of the proffered figures may even be suspect and in most cases they are likely to be very incomplete.

The speaker, after two decades of practical experience in one branch of the work of collecting and assessing such data, is impressed with the need for intelligent sifting if the result is to be of any real value. Such analysis cannot be performed by an untrained man, for it often requires a knowledge of the deposits and at times demands field research before the desired facts emerge. As a nation we have not been too well equipped during the last few years to undertake research of this kind in a thorough fashion because there has not been a geological and mining staff at the call of our ministers at the legations, especially in the younger, sparsely populated and richly mineralised countries.

If this conspectus of mineral resources suggested by Prof. Boswell is to be carried out perhaps the British Association may use its powerful machinery to bring to official notice this need, this present and pressing need, for the introduction of specialists in earth lore to the precincts of the Foreign Office.

Sir Harold Hartley, C.B.E., M.C., F.R.S.

MAY I first add the appreciation of another chemist to the work of the geologists in their survey of the world's mineral resources. Prof. Boswell has told us that geologists are not fully occupied at present with war work, and has emphasised the need for statistics as a preliminary to the Atlantic Charter. Prof. Read has spoken of the unawareness both of the public and the politician of the significance of the issues that are raised by a survey of our national resources. The lack of statistics I can confirm from my own experience in writing my paper on the Recovery of Metals from Scrap, as the only statistics available are those compiled in the United States. I should like to draw attention not only to the importance that is attached in Washington to the preparation of comprehensive statistics of every factor affecting national existence in the United States, but to the presentation of those statistics in a form that is readily intelligible both to the public and the politician.

One of the first acts of Mr. Roosevelt in 1934 was to establish the National Resources Board with the duty of making an inventory of the national resources of the United States. The first General Report of the Board issued in 1935 was a model of clarity and presentation. It gave a picture of the human and material resources of the United States and their present utilisation in a most attractive and intelligible form which revealed very clearly the problems which that country has to face. A report on similar lines of our Empire resources would be of the greatest educational value and an essential preliminary to the planning of reconstruction.

Fuel and power are one of the few fields in which international statistics are available, due to the voluntary co-operation organised by the World Power Conference. The annual Statistical Yearbook of the W.P.C. gave a running picture in peace time of the production, consumption and resources of fuel and power in each country, the details of which could be filled in from the Transactions of the International World Power Conferences which are held at frequent intervals.

This shows what can be done by voluntary co-operation, but unfortunately it has not existed in other fields on the same scale. I suggest, therefore, that the compilation of comprehensive statistics of world resources and their utilisation is a matter of immediate urgency as a basis for any plan under Clause 4 of the Atlantic Charter. In so far as the British Empire is concerned, the presentation of such statistics in a simple form, similar to the Report of the National Resources Board of the United States, is an equally urgent task.

Mr. Philip Rabone, A.R.S.M., D.I.C., M.Inst.M.M.

IT is evident that neither the Mines Department nor the D.S.I.R. as constituted at present is competent to develop the mineral wealth of Great Britain and the Empire in accordance with the terms of the Atlantic Charter. Something in the nature of a Bureau of Natural Resources will be needed, constituted on the lines of the United States Bureau of Mines or of similar organisations in the U.S.S.R. and Canada. There is no comparable organisation in Great Britain except, in a small way, the Imperial Institute. This institution has a Charter which is based on ideals such as those of the Atlantic Charter, and it is doing fine work for the Empire in spite of inadequate funds. It could well form the basis on which to build up a Bureau of Natural Resources.

Mr. A. S. Pye-Smith

As a manufacturer of alloy steels and as a student of geology, I have listened with great interest to the addresses given this morning.

There is one matter to which, in the interests of historical and scientific accuracy, I feel I must draw attention. Sir Richard Gregory, in his opening remarks, after referring to Faraday's work, spoke of Sir Robert Hadfield's production of manganese steel [which began about 1883] as 'marking the beginning of the age of special alloys.' Without for one moment depreciating the value of Hadfield's discovery, I wish to refer to the earlier work on alloys of David Mushet and of his son Robert Forester Mushet. Both these men were actually engaged in the manufacture of iron and steel. The former did a great deal of experimenting and it is partially described in his 'Papers on Iron and Steel' published in 1840; the latter continued the work, but, unfortunately, few records of his results survive. The importance of their work on manganese and tungsten alloys has been fully acknowledged by Hadfield himself in various papers.

Sir Thomas Holland spoke of the use of manganese in the Bessemer process, and Prof. Fawcett of the important part played by improvements in cutting-tools in the upward progress of mankind. Now, it was Robert Mushet who, in 1856, enabled the Bessemer process to be perfected by suggesting the addition of carbon and manganese to the blown metal by the use of spiegeleisen. But in 1868 he produced his famous 'R. Mushet's Special Steel'—a self-hardening tool steel containing not only manganese, but tungsten, and, later, if not originally, chromium as well. This improved cutting-tool steel was greatly prized by mechanical engineers and was the forerunner of the modern high-speed tool steels. In his paper on 'The Development and Use of High-Speed Tool Steel' (1904), Mr. J. M. Gledhill wrote, 'A very important advance was made thirty or forty years ago, when "Mushet," or self-hardening steel, was introduced. This was the valuable invention of Robert Mushet, who, after a long series of experiments whilst he was manager of the Titanic Steel Company, succeeded in producing a tungsten steel, and its introduction was a great advancement on the cutting-powers of ordinary crucible steel, and for many years "Mushet" steel held a foremost place amongst tool steels.' It was produced by my firm for over thirty years under the superintendence of Mushet's sons until quickly superseded by high-speed steel after the Taylor-White exhibit at the Paris Exhibition of 1900. It may justly be claimed, I think, that this alloy steel was of even wider importance to mechanical engineering than manganese steel, and its introduction anteceded the discovery of the latter by fifteen years.

Friday, July 24: Afternoon Session

Address by
Sir Wm. J. Larke, K.B.E.
Chairman

It is well to remind ourselves that in the first twenty-five years of the present century more metal of every kind was produced and used than in the whole of previous historic time, and it is not unlikely that the end of the second twenty-five years of the present century will find even that rate of consumption doubled.

It has been well stated that mankind can only be interested in Nature's slag dump, since that is the constitution of the first ten miles of the earth's crust. Clarke and Washington (of the U.S.A. Geological Survey) estimated that 98·6 per cent. of the earth's crust consisted of only eight elements, of which oxygen represented 46·6 per cent., silicon 27·7 per cent., aluminium 8 per cent., iron 5 per cent., and the other four (calcium, sodium, potassium and magnesium) between 2 per cent. and 3 per cent. each. Of minerals, iron may be said to have exercised, so far, the greatest material influence on the development of mankind, 90 per cent. of the metal used being iron alloyed with small proportions of other elements. Rickard, in his *Man and Metals*, pointed out that the marriage of coal and iron at Coalbrookdale in Shropshire in 1735, at which Abraham Darby officiated as High Priest, gave birth to the Industrial Revolution. Prior to the successful smelting of iron by stone coal, the industry was based on wood and located for the most part in Kent, Surrey and Sussex in this country; and Sweden, then the largest producer in the world, was entirely dependent on charcoal smelting. Even to-day Sweden has to import coal and coke. In this country the result was the reversion of Kent, Surrey and Sussex to agriculture, and the growth of our iron and steel producing centres where coal and iron ore were found.

Thus in this case geological and geographical distribution exercised a profound influence on the development of this country, and subsequently Europe and the World as a whole. As it became possible, through the advance in technical knowledge and the inventions of Gilchrist and Thomas, to smelt the phosphoric ores of the Continent, we have the result in Europe in our modern steel civilisation, if 'civilisation' is the appropriate word to apply to the present state of the world, and Axis Europe in particular.

It will be noted that aluminium represents 8 per cent. of the earth's crust; yet while its use has grown enormously and its production increased over thirty times in the first twenty-five years of the present century, it is still only a small fraction of that of iron and its alloys, owing to the present difficulty of extracting it. Yet light alloys of magnesium and aluminium have made most remarkable and phenomenal progress, some of them possessing many of the physical qualities of steel at one-third of the weight; and if investigations into the possibility of extracting aluminium from clay (which were in progress at the outbreak of war) prove successful on a commercial scale, it would render possible remarkable developments in engineering applications.

Would the distribution of bauxite throughout the world affect the location of this development? At present it would seem that cheap electric power would be a much more potent factor, although for reasons partly economic but mainly strategic Germany has built up an important

aluminium industry based on steam generated electric power and largely imported bauxite. The lesson to be learned from this and similar examples is that cheapness is not the only factor which a country should take into consideration in determining its policy in relation to primary materials.

But there are many other elements (available in such small quantities that they are properly described as 'rare', e.g. tin 0·0004 per cent., tungsten 0·005 per cent., and nickel 0·02 per cent.) which exert a profound influence on our modern life and consequently on the military strength of the countries which know how to use them and can obtain them. In these days of ever-increasing rapidity of transport, under peace conditions it would seem to be possible for all nations to obtain access to the raw materials they require (irrespective of their geographical location), if willing to pay the world price for them. This has been fully borne out by the large stocks of essential metals—such as tungsten, nickel and chromium—which Germany was able to accumulate before the outbreak of the present war, none of these being available in Germany. Although the Allies' blockade has no doubt materially reduced (where it has not completely cut off) supplies during the war period, it has been proved to be possible to carry on a gigantic war effort on such stocks for at least the last three years. No doubt changes in technique, readjustment of the constitution of alloys, and so forth, have done much to conserve resources and extend their use in Germany.

While war of necessity increases the volume of production of minerals already available for its service, by its very character and urge for rapidity of action it delays the development of long-range research and experiment. At the same time it unquestionably gives an impetus to new applications through the necessity for substitution of one material for another. In many cases it is obvious that this substitution must be made as a matter of expediency rather than on the grounds of economy or efficiency; but in many others the substitution imposed by war conditions may result in entirely new permanent applications of an economic and far-reaching character.

The greatest need for the post-war period appears to be accurate knowledge as to the geological and geographical distribution of the essential minerals on which the material well-being of mankind is based. Particularly the correlation of the vast amount of existing knowledge in a statistical form which will enable effective comparison to be made as to the progressive development in the different countries. On such knowledge alone can an effective policy, either national or international, be devised in respect of the distribution of mineral resources. In spite of the wealth of information which is published by different authorities, we are frequently still unable to ascertain with accuracy economic information of the known mineral occurrences, even of the United Kingdom, which has been the home of mining, and was one of the principal sources of supply of non-ferrous metals to the Old World for upwards of a thousand years.

While the Mineral Resources Department of the Imperial Institute, which is the centre for the collection and dissemination of information, including statistics, of the mineral resources of the Empire, is maintaining the collection of statistics (although under present conditions they are not available for publication), great difficulty has been experienced in the past in securing statistics from the different Dominions and Colonies on a comparable statistical basis. At two Imperial conferences proposals were made that such a basis should be established, but so far it has not been accomplished. It would involve the full collaboration of the commercial mining interests responsible for mineral development within the Empire, but this it is believed can be readily secured. It will be obvious that such information will be necessary for the effective regulation of the distribution of minerals, and it is to be hoped that the efforts which the Imperial Institute is making will prove ultimately successful.

The fourth clause of the Atlantic Charter, however, still has an important bearing on future policy in that it is a pledge that no restrictions will be placed on access by all nations to raw materials. This may have a much more important bearing on the future than we at present realise, since in the light of present knowledge the deprivation of certain metals (such as tungsten, nickel and chromium) would make a nation almost defenceless against others which could obtain them. There is strong evidence that we are passing through another Industrial Revolution based on an ever-increasing understanding of the potentialities of alloys of basic metals (such as iron, aluminium and copper, with small and even minute proportions of other elements) which completely change the physical properties of the basic metals with which they are alloyed, thus producing alloys possessing physical characteristics undreamed of even at the beginning of the present century.

There is no doubt that the economic co-operation between the United Nations envisaged by the Atlantic Charter will be essential if world recovery is to be accomplished within a generation. Therefore the national organisation of production of all kinds is a condition precedent to international regulation of the distribution of the products. This will apply particularly to raw materials whether mineral or agricultural. The production of such materials is to some countries the basis of their economic life, and unless they can be exported to countries able to use them, hardship and a fall in the standard of life of those countries becomes inevitable.

To achieve Article 5 of the Atlantic Charter—to improve labour standards and social security—it must be one of the objects of international co-operation to ensure that countries producing primary materials, whether mineral or agricultural, are able to secure a reasonable return for their labour by world regulation of distribution and international control of the price level. The objective should be to maintain the maximum interchange of raw materials and industrial products. The purchase of raw materials below the cost of production in the countries of origin by industrial countries, due to fortuitous circumstances consequent upon unregulated distribution, can only have the effect in the long run of reducing the consuming power of the countries

affected for industrial products, and thus react adversely on the industrial countries themselves and on the productive activity of the world as a whole. It cannot be expected that complete regulation in all fields of productive activity can be achieved except over a long period of time, but to the extent that it has been achieved already in some spheres of productive activity ; an improvement due to the creation of relatively stable economic conditions has been substantial, and the fluctuations in productive activity materially reduced.

However desirable the doctrine of *laissez faire* may have appeared in a world emerging from a state of primitive individualism, it is obvious that its general application under to-day's conditions would be the denial of the intelligent application of the results of experience. This is not to say that discretion must not be used in the regulation of productive activity and distribution so as to avoid restriction on initiative and enterprise ; but as Lord Milner so aptly said in another connection : 'A man need not be a drunkard because he takes a nightcap of whisky and soda.'

The fact that the Atlantic Charter appears to envisage such regulation is of the utmost importance, but to achieve the result will involve 'give and take' and sacrifice at the outset to a greater or lesser extent on the part of all participating nations. The ultimate result of such a policy to the extent that it can be achieved would unquestionably benefit all the participating nations and ultimately raise the standard of life for mankind as a whole. It would also create world conditions under which the chances of maintaining peace would be greatly enhanced, since some, if not most, of the economic causes of war would be adjusted by agreement as they arose.

Up to the present, we as a nation are neither research nor technically minded. Our policies, therefore, do not always take sufficiently into consideration the possibilities created by scientific knowledge and technical application. We are thus far too frequently placed at an unnecessary disadvantage in relation to the rest of the world, even when, as in so many if not most fields, we lead the world both in scientific discovery and technical achievement, but leave exploitation of our work to others, following, instead of maintaining the lead we establish.

Some measure of responsibility rests on the scientists and technicians for not presenting their work to the public in a 'language understanded of the people' and thus exerting a greater influence on public opinion. This was recognised by no less an authority than your revered late President, my old friend Sir Alfred Ewing, who, in his Presidential Address to this Association in 1932, said : 'Experts gain by indulging in an interval of comparatively lucid self-expression.'

Prof. W. R. Jones

Tin Resources and the Atlantic Charter

THE world's supply of tin metal is obtained virtually from one mineral only, cassiterite, the oxide of tin.

It is fortunate that this mineral possesses chemical and physical properties which enable it to withstand weathering processes to such degree that it remains unaltered throughout geological ages. Even in the oldest stanniferous gravels, cassiterite is in the same state as when originally formed.

Tin deposits of economic importance occur in but few parts of the earth's crust and it is a striking anomaly that the country that uses most tin has practically no domestic supply, whereas the most productive tinfields are in countries where little or no use is made of the metal. It would thus be difficult to name a metal, or even any commodity, which could better serve than tin to illustrate the significance of one of the principles enunciated in the Atlantic Charter.

The United States of America, for example, uses over 40 per cent. of the world's tin production, but in the whole of that country and in Canada there is not a single tin mine. The average domestic production of tin in the U.S.A. for the last hundred years was less than eight tons annually, in Canada less than one ton, all obtained in both countries as a by-product from mines worked for other metals. If the total domestic tin production of the whole of North America for the last hundred years had been stored it would not be sufficient for the present tin consumption of U.S.A. alone for one week.

In Europe the average production over a long period of years has been less than 2 per cent. of world consumption, and more than half of that amount has been obtained from a few square miles in Cornwall, which, however, for the ten pre-war years produced little more than 1 per cent. of that of the world.

On the other hand, countries like Malaya, Burma, Thailand, Netherlands East Indies, China, Nigeria, Belgian Congo and Bolivia produced together in normal times 93 per cent. of the world's supply of tin, yet most of these have no domestic industrial use for the metal. In brief, the countries that require most tin import almost all they use, and those which yield most use least.

Let us consider in outline why it is that some few parts of the crust are rich in tin deposits and why half-continents contain no such natural resources, for it is not lack of money, knowledge or intense search by eminent geologists and mining engineers that accounts for the failure, after numerous attempts, to locate even one workable tin deposit in U.S.A. and Canada. The reason is simple : the geological setting in these two countries was not suitable for tin mineralisation on an economic scale.

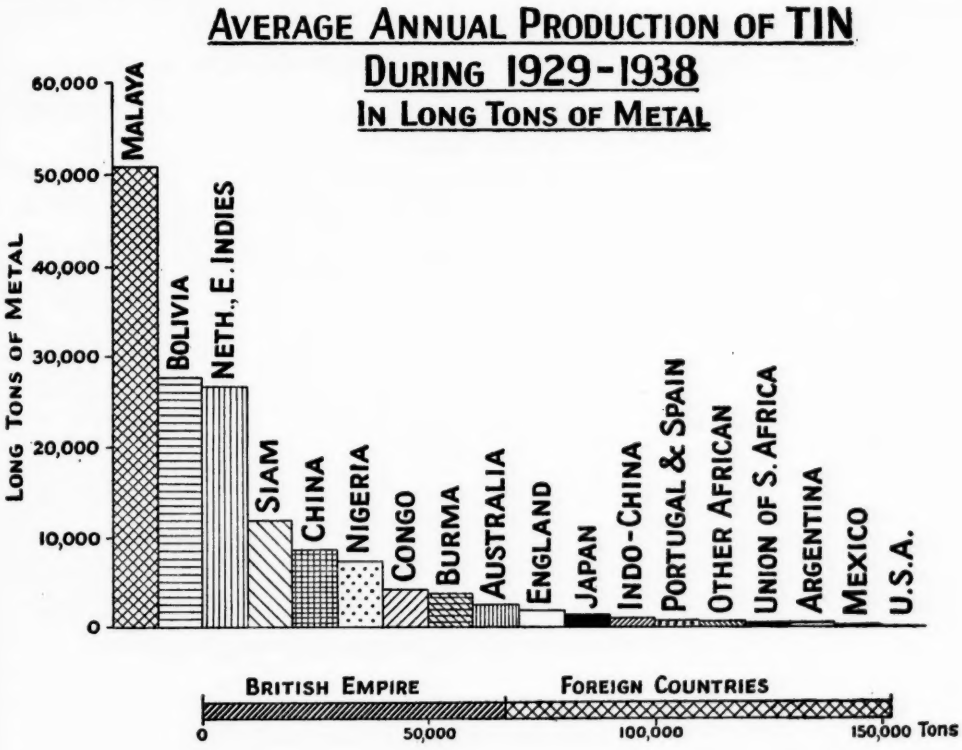
Nowhere in the world has any tin deposit been formed *in situ*, except where the mineralisation is genetically related to granite, or to rocks of the granite family such as granite pegmatites, associated magmatic quartz veins, aplites, rhyolites and quartz porphyries or elvans as they are termed in Cornwall. It is true that rich tin lodes have been worked successfully some distance from the granite contact, as in the 'killas' in Cornwall and metamorphosed sedimentaries in other countries, but even there the cassiterite is in veins or lodes composed of material derived from granite or granitic magma. Furthermore, the cassiterite in alluvial and eluvial stanniferous deposits is derived from weathered mineralised areas intimately associated with these same types of igneous rocks.

Unfortunately, only certain types of granites and granitic rocks have given rise to tin mineralisation. In U.S.A. and Canada, granite and allied rocks occur over very extensive areas, and although some of these have played an important rôle in the formation of highly productive copper and gold deposits, the conditions during their consolidation were not amenable for tin mineralisation.

It would overburden this address to describe in detail the geological environment which is suitable for tin mineralisation. It will suffice for present purposes to state that the essential conditions obtain in only comparatively few parts of the crust. Thus it is that the world's chief tinfields can be resolved into a few groups which can conveniently be termed 'metallogenetic tin provinces,' that is, parts of the crust where tin mineralisation, with respect to each group or province, was effected at the same geological period and under similar, or almost similar, conditions. A brief outline of one of the chief of the world's metallogenetic tin provinces will serve to exemplify this conception of the grouping of a number of tinfields into a geological unit.

In the Malay Peninsula tin deposits occur in all the Federated and the Unfederated Malay States; they occur in Thailand to the north and in Lower Burma; and southwards, rich tin deposits are found in the islands of Banka, Billiton and Singkep of the Netherlands East Indies. In all these countries they are associated with the same type of granite and granitic rocks, have very similar features, and the geological evidence is strong for presuming that the primary deposits in that part of the world were formed during one and the same period of tin mineralisation. This metallogenetic tin province yielded, for the ten pre-war years, an average of over 60 per cent. of the world's tin production. Further knowledge may show that the tinfields of Indo-China and even those of Mawchi in Burma and Yunnan in China are parts of this same metallogenetic province. The areas now occupied by Japan, it may be added, produced in pre-war days over 62 per cent. of the world's tin.

The chief groups of tinfields with their average annual percentage of world production for the ten pre-war years are shown on the accompanying map and are as follows :—



	Per cent.
(1) Malaya, Burma, Thailand and Netherlands East Indies	61·7
(2) Bolivia	18·0
(3) China	5·7
(4) Nigeria	4·9
(5) Belgian Congo	2·6
Total	92·9

By far the greatest production in all these, except Bolivia, was obtained from alluvial and eluvial deposits. When it is considered that in Malaya one tin dredger in one day could recover more cassiterite than would be accumulated throughout the whole of the Malay Peninsula by natural processes in more than a generation, it requires no imagination to realise what the result must be in the course of years. For example, the alluvial deposits in Taiping District in Malaya, once a highly productive tin dredging area, have been exhausted and certain other productive areas have passed their zenith of production. In fact, the history of tin mining will inevitably

repeat that of gold mining. Within living memory the bulk of the world's gold was obtained from auriferous gravels ; in recent years most of it comes from lode mining.

The question arises as to where, in future, the world's tin requirements will be produced, or what possibilities there are of the discovery of new tinfields in hitherto unprospected parts of the world. Geologists and mining engineers travel well beyond the ordinary lines of communication, and not many parts of the earth's surface remain completely unknown to them. Moreover, the igneous rocks which favour tin mineralisation usually form prominent topographical features, and the panning of neighbouring stream beds provides a ready means of ascertaining the presence of cassiterite.

It is reasonable to assume that most of the world's tin will be obtained from tinfields already known ; also that some of these, like parts of Malaya, Burma, Netherlands East Indies and particularly of Nigeria, will, after the exhaustion of the surface deposits, become very considerably less productive. It is true that in places in Malaya, for example, lode mines were in operation until recently, but the greatest amount of Malayan cassiterite was obtained from alluvial deposits derived from stockworks and disseminations which would not be workable in depth in undecomposed rock. It would seem to be conclusive that lode mining areas will, in future, become of increasing importance following the exhaustion of the more easily worked but far less persistent secondary deposits.

The significance of all this with respect to the distribution of the world's tin resources is that the countries that use most tin are, and will remain, dependent on other countries for their supply of this essential metal.

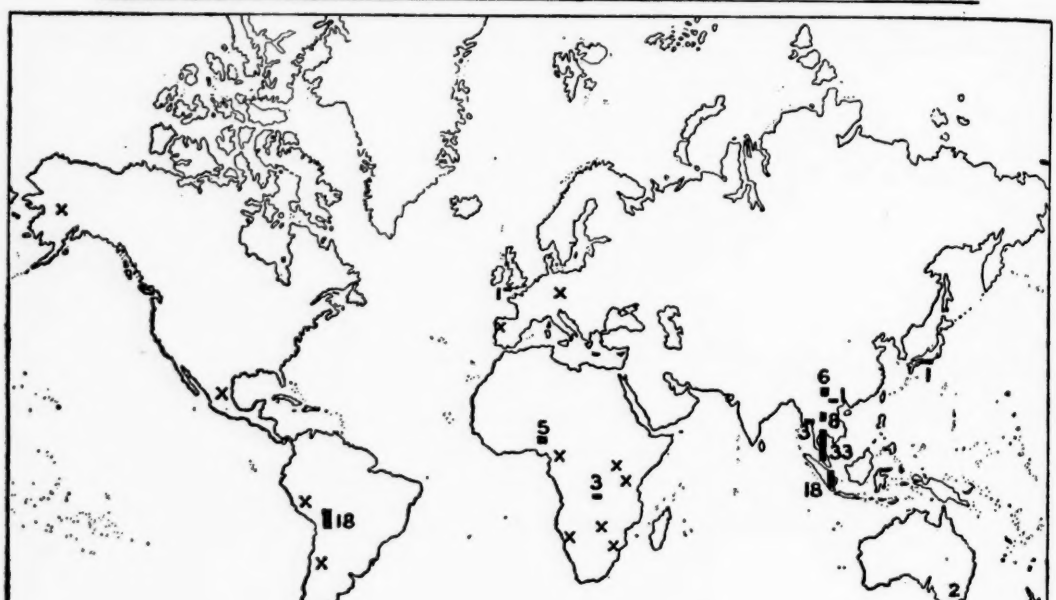
Sir Lewis Leigh Fermor, O.B.E., F.R.S.

The World's Manganese-Ore Deposits and the Atlantic Charter

I.—Introduction

In this morning's session Professor Read has explained how elements originally sparsely or evenly distributed in the crust of the earth become by geological processes concentrated into metalliferous bodies rich enough to be of economic use to man, such commercially usable concentrations being termed *ore-deposits*. These processes result in a very uneven distribution of valuable mineral deposits amongst the countries of the world, so that no country is completely self-sufficient in the great variety of minerals used by modern man to satisfy his multifarious needs, economic, engineering, scientific, or military. Every country that enters into the field of modern industry is compelled to rely for a portion of its mineral needs upon imports from abroad.

The purpose of this afternoon's session is to illustrate this uneven distribution of essential minerals by the discussion of four selected groups of metallic ores, namely those of aluminium, manganese, nickel, and tin, all essential in industry, engineering, and armaments : and to relate this uneven distribution to Clause 4 of the Atlantic



Charter. Of these manganese-ores have been allotted to me.

According to F. W. Clarke [1] only 0·10 per cent. of the earth's crust consists of manganese oxide (MnO). It is not usual, however, to describe as manganese-ores, without the use of qualifying adjectives such as 'ferruginous,' mineral substances containing less than 40 per cent. of metallic manganese, though in the United States, where high-grade ores are scarce, the lower limit is taken as 35 per cent.[2]

The lower limit of manganese for first-grade ore was formerly 50 per cent. and is now 48 per cent., but a large proportion of the manganese-ore of commerce contains at least 50 per cent. of the metal. This means that Nature in producing these ores has concentrated the originally widely dispersed element to the extent of some 500 times to produce the ores we now use.

II.—The Mode of Occurrence of Manganese-Ores in Nature

Manganese-ores occur mainly in beds of sedimentary origin, associated with contemporaneously deposited sandstones, shales, and limestones, the manganese having been deposited either as oxides or carbonate, sometimes subsequently metamorphosed, with compaction of the ores, or, if less pure, with formation of manganiferous silicates, such as spessartite-garnet and rhodonite. In such cases the carbonate and silicates have often been later converted or reconverted to oxides at the surface as a result of surface oxidation processes. In addition smaller quantities and bodies of ore have been formed, often in nodular form, as residual deposits at the surface from the weathering or alteration of rocks in which the element was only sparsely present; amongst such residual deposits must be mentioned the lateritic manganese-ores, of similar origin to lateritic iron-ore and aluminium-ore (bauxite) deposits. Deposits in mineral veins of manganese minerals by solutions from below are quantitatively rare and unimportant, the outstanding exception being the rhodochrosite or carbonate deposits of Butte in Montana, U.S.A., which constitute that country's most important source of manganese-ore.

It is not surprising that an element so prone to oxidation as is manganese, and so generally present in rocks, even though in such small proportion, should have given rise to workable deposits in formations of almost all geological periods from Archaean to Recent; nor that manganese-ore deposits should be found in almost every country. The vast proportion of these deposits are, however, relatively small or quite unimportant. In fact, although manganese-ore is produced by more than forty countries, only seven have produced on the average over 100,000 tons annually during the last quinquennial period before the present war, 1934 to 1938, as is shown by the following figures :—

Average Annual Production of Manganese-Ore, 1934 to 1938.

	Long tons
Russia	2,552,820
British India	776,151
Gold Coast	411,621
South Africa	313,566
Cuba	146,822
Brazil	138,051
Egypt (Sinai)	110,756
Other countries (32) [1]	399,693 [2]
	4,849,480

Further, and surprisingly, the production from these seven countries comes mostly from formations lying near the two ends of the geological time-scale. For the Russian (Oligocene and Lower Eocene) and Cuban (Upper Eocene) deposits are in the Lower Tertiary, whilst with the exception of the Egyptian (Carboniferous) deposits all the other ores come from the pre-Cambrian.[3]

III.—The Geographical Distribution of Manganese-Ores

In discussing the geographical distribution of mineral deposits it is customary to speak in terms of present countries and continents. Whilst this is sound for countries because of the existence of national boundaries, it is not necessarily so for continents, particularly if the distribution of ore deposits is, in fact, related to the distribution of former continents, and not to that of existing continents, as seems to be the case with manganese ores and some other minerals.

It is necessary, therefore, to introduce you to the geological conception of *Gondwanaland*, a former continent, the existence of which is accepted by most geologists on the evidence of fossil floras and of a former (Upper Carboniferous) ice age in India, South Africa, Australia, South America, and Antarctica. The fragments of this

[1] *Data of Geochemistry*, p. 32 (1916).

[2] The classification proposed by me many years ago, and one that seems to have met with approval, is as follows :—

	Mn per cent.	Fe per cent.
Manganese-ores	40 to 63	0 to 10
Ferruginous manganese-ores	25 to 50	10 to 30
Manganiferous iron-ores	5 to 30	30 to 65
Iron ores	0 to 5	45 to 70

See 'The Manganese-Ore Deposits of India,' *Mem. Geol. Surv. Ind.*, XXXVII, p. 500 (1909).

[1] These include Czechoslovakia, with an output of 104,664 tons in 1937, and an average of about 85,000 tons annually for the period; and Japan with an average annual output of about 67,000 tons. The Czechoslovakian ore averages only about 17 per cent. of manganese, however.

[2] The statistical data used throughout this paper are taken from the Statistical Summaries of the Mineral Industry, published by the Imperial Institute. In addition, the reader will find much interesting geological and statistical data in the excellent monograph on 'Manganese,' by Dr. A. W. Groves, which has already reached its second edition (1938), also issued by the Imperial Institute.

[3] With the doubtful exception of the South African deposits of the Postmasburg area, which are found in pre-Devonian rocks, which are probably also pre-Cambrian, but may be in part as late as early Cambrian. A small proportion of the Indian production is from lateritic deposits formed by the surface alteration of pre-Cambrian rocks.

southern continent are shown in the accompanying figure, a diagram due to Dr. A. Holmes.[1]

The remainder of the present land surface of the earth belongs partly to another former continent known as Laurasia and partly to the mountain belts (representing the former belt of separating

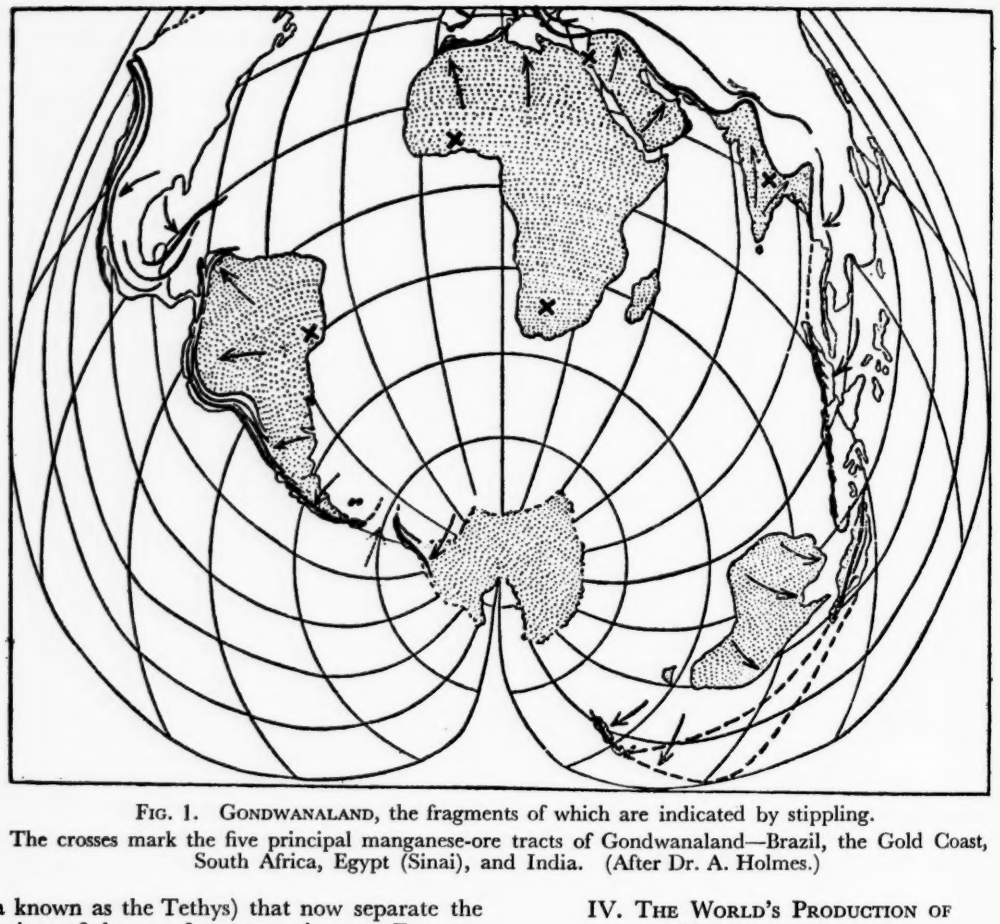


FIG. 1. GONDWANALAND, the fragments of which are indicated by stippling.
The crosses mark the five principal manganese-ore tracts of Gondwanaland—Brazil, the Gold Coast, South Africa, Egypt (Sinai), and India. (After Dr. A. Holmes.)

sea known as the Tethys) that now separate the portions of the two former continents. For convenience in discussing statistics we will refer to Laurasia plus these mountain belts as Non-Gondwanaland.

Views differ as to how Gondwanaland was broken up. The earlier view was that the intervening land sank below the oceans. The more modern view, to which many but not all geologists subscribe, is that the fragments we now see constitute roughly the major portion of this former continent and that they have become separated by slow floating apart on a plastic or potentially plastic substratum or shell of the earth, situated perhaps some 60 kilometres or 37 miles below the surface.

If we now look back at the list of the seven principal manganese-ore producing countries of the world we find that five of them belong to Gondwanaland, and that only two are in Non-Gondwanaland, namely, Russia and Cuba ; and that the Gondwanaland deposits are of pre-Cambrian age, except for the carboniferous deposits of Egypt, whilst the Non-Gondwanaland deposits are of Lower Tertiary age. We thus find that there was a period of manganiferous deposition at the lower end of the geological column in Gondwanaland, and with no important analogue in Non-Gondwanaland : and a period of manganiferous deposition towards the upper end of the geological column in Non-Gondwanaland, with no important analogue in Gondwanaland.[1]

[1] *Mining Magazine*, vol. 40 (1929).

IV. THE WORLD'S PRODUCTION OF MANGANESE-ORES

Accordingly, in Table No. 1, showing the world's manganese-ore production for the five years 1934 to 1938, I have thought it instructive to arrange the countries according to their situation in Gondwanaland or otherwise. From this table it will be seen that over this quinquennial period Gondwanaland produced 36·42 per cent. of the world's manganese-ore, Russia 52·64 per cent., and the remainder of Non-Gondwanaland only 10·94 per cent. These percentages give an illuminating view of the uneven distribution of the world's manganese-ore deposits.

V.—THE USES OF MANGANESE-ORES

What is next of interest is what happens to the manganese-ore output of the world. It may be stated at once that at least 90 per cent. of the world's manganese-ore production is consumed in

[1] That Gondwanaland is a reality from the point of view of minerals of economic value is shown by other peculiarities of distribution of mineral wealth, of which two may be mentioned here. More than 99·99 per cent. of the world's diamonds come from Gondwanaland, and more than half the gold, whilst all the really deep gold mines are in Gondwanaland.

the iron and steel industry,[1] mainly in the production of ferro-manganese (and to a certain extent of spiegeleisen, and the other alloys silico-manganese and silico-spiegel), an alloy that is added to the steel melt in order to remove from the molten steel certain impurities that would otherwise impair the properties of the finished steel, and though some manganese-ore is used for the manufacture of manganese-steel; whilst, in some cases, manganese-ore is added to the blast-furnace burden, either as such, or as manganiferous iron-ore. No satisfactory commercially usable substitute has been found for manganese-ore in the steel industry, although

TABLE 1.—*The World's Production of Manganese-Ore*, 1934 *to* 1938

	Long Tons					
	1934	1935	1936	1937	1938	Mean 1935–1938
GONDWANALAND :						
America :						
Brazil	2,300	(*e*) 59,711	153,734	256,054	218,455	138,051
Argentina	574	432	436	596	(*a*) 500	508
Africa :						
Gold Coast	365,178	430,659	(*e*)411,024	(*e*)527,036	(*e*)324,207	411,621
South Africa	64,463	93,943	254,167	621,229	534,028	313,566
Egypt (Sinai)	944	85,924	132,840	183,377	150,694	110,756
Belgian Congo	—	—	—	30,498	7,603	7,620
Northern Rhodesia	2,041	3,976	3,022	2,341	2,735	2,823
Asia :						
British India	406,306	641,483	813,442	1,051,594	967,929	776,151
Portuguese India	3,800	4,000	2,579	4,013	9,478	4,774
Australia	105	148	72	1,142	594	412
Total : Gondwanaland	845,711	1,320,276	1,771,316	2,677,880	2,216,223	1,766,282
NON-GONDWANALAND :						
Russia	1,792,200	2,346,900	2,955,000	2,770,000	2,900,000	2,552,820
Cuba	267,115	90,650	151,981	113,840	110,523	146,822
Czecho-Slovakia	58,433	70,306	91,567	104,664	(*a*)100,000	84,994
Japan	56,262	70,527	66,683	(*a*) 70,000	(*a*) 70,000	66,694
Morocco (French)	7,161	24,479	29,412	75,257	85,230	44,308
Roumania	11,867	19,482	33,321	49,947	59,222	34,768
United States	26,514	26,428	32,119	40,241	25,321	30,125
Unfederated Malay States	18,649	28,045	36,777	32,793	31,970	29,647
Italy	6,831	8,983	24,343	33,002	47,529	24,137
Hungary	10	6,192	26,798	24,691	21,870	15,912
Netherlands East Indies	11,451	12,158	8,483	10,908	9,534	10,507
Philippine Islands	—	511	200	5,600	40,240	9,310
Germany	507	220	238	177	200	268
Other countries (16)	22,005	38,557	33,457	42,312	28,095	32,886
Total : Non-Gondwanaland	2,279,005	2,743,438	3,490,379	3,373,432	3,529,734	3,083,198
TOTAL : Gondwanaland + Non-Gondwanaland	3,124,716	4,063,714	5,261,695	6,051,312	5,745,957	4,849,480

(*a*) Estimate. (*e*) Exports.

product. This is the chief use of manganese in the iron and steel industry, though the manganese left in the steel itself affects favourably the quality many possibilities have been tested. Hence the successful manufacture of steel by any country is dependent upon an adequate supply of manganese ore, or of ferro-manganese (or spiegeleisen) manufactured therefrom.

[1] The other chief uses for the manufacture of certain non-ferrous alloys; as peroxide in dry batteries; in the glass and ceramics industries, both as a decolorising agent, and as a colouring agent; as a dryer for oils, paints and varnishes; in the manufacture of pigments; and in the chemical industry and agriculture. Some of these uses depend on the colouring effects of manganese compounds—violet, green, black—and others on the great affinity of manganese for oxygen, as exemplified by the existence of the mineral pyrolusite, a prolific source of oxygen.

VI.—THE WORLD'S STEEL OUTPUT

To understand what happens to the manganese-ore output of the world it is important, therefore, to know the chief steel-producing countries of the world. The most active recent pre-war year in the iron and steel industry was 1937. I show below, therefore, in descending order of magnitude, the output of steel ingots and castings in

TABLE 2.—*The World's Exports of Manganese-Ore*, 1934 *to* 1938

	LONG TONS					
	1934	1935	1936	1937	1938	Mean 1934 to 1938
GONDWANALAND :						
Brazil	2,264	59,711	163,842	243,212	134,682	120,742
Gold Coast	339,985	398,718	411,024	527,036	324,207	400,194
South Africa	65,179	80,222	204,558	474,633	314,012	227,721
Egypt	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	100,000 (*a*)
Belgian Congo	—	—	—	27,597	3,251	6,170
British India	394,296	702,287	633,823	981,189	518,342	645,987
Portuguese India	—	—	2,397	5,282	3,847	2,305
Australia	—	—	—	2,090	2,095	837
Total : Gondwanaland	801,724	1,240,938	1,415,644	2,261,039	1,300,436	1,503,956
NON-GONDWANALAND :						
Russia	725,237	634,689	596,166	984,999	(*c*)385,000	665,218
Cuba	66,658	49,783	36,053	131,936	110,523	78,991
British Malaya (*d*)	18,653	26,842	36,758	34,024	30,570	29,369
Morocco (French)	4,468	24,477	27,414	31,212	42,722	26,059
China	856	814	23,418	50,633	1,227	15,390
Philippine Islands	—	12	251	12,013	48,580	12,171
Netherlands East Indies	7,047	9,871	11,215	15,444	11,044	10,922
Belgium and Luxemburg, Econ. Union	10,100	6,836	12,123	2,775	13,704	9,108
Chile	4,000	4,301	5,102	12,810	19,000	9,043
Turkey	—	15,334	4,572	—	2,692	4,520
Japan	4,545	5,177	5,637	5,562	2,426	4,669
Hungary	—	30	5,292	13,659	(*b*)	3,796
Germany	2,049	1,591	1,316	788	758	1,300
Italy	25	1	—	26	1	11
Other countries (13)	7,725	11,205	12,761	14,654	11,840	11,637
Total : Non-Gondwanaland	851,363	790,963	778,078	1,310,535	680,087	882,204
TOTAL : Gondwanaland + Non-Gondwanaland	1,653,087	2,031,901	2,193,722	3,571,574	1,980,523	2,386,160

(*a*) Estimated. (*b*) Information not available. (*c*) Estimated from eleven months' data. (*d*) Including re-exports.

1937 by all countries that turned out one million or more tons of steel in that year :—

World's Output in 1937 *of Steel Ingots and Castings*

	Long tons
United States	50,568,701
Germany	19,050,372
Russia	17,149,000
United Kingdom	12,984,000
France	7,794,997
Japan (with Korea)	5,719,488
Belgium	3,801,586
Luxemburg	2,470,588
Czechoslovakia	2,254,879
Italy	2,065,582
Poland	1,428,023
Canada	1,402,882
Australia	1,097,639
Sweden	1,088,141
India	895,229
Other countries (9)	2,528,893
	132,300,000

The fact of greatest interest in the above figures from the point of view of the present paper is that the Gondwanaland countries Australia and India, with South Africa (279,700 tons) and Brazil (75,223 tons), produced between them only 2,347,791 tons of steel, or only 1·77 per cent. of the world's output of steel, although the Gondwanaland countries in that year produced 44·25 per cent. of the world's manganese-ore ; instead, all but a small proportion of the manganese-ore output of the Gondwanaland countries was exported to countries outside Gondwanaland. Russia is the only example of a large producer of manganese-ore being also a large producer of steel.

VII.—THE WORLD'S EXPORTS OF MANGANESE-ORES

The export statistics of manganese-ore for the world for the five years 1934 to 1938 are shown in Table No. 2, from which it will be seen that although during this quinquennium the Gond-

wanaland countries produced annually on the average only 36·42 per cent. of the world's manganese-ore, they were responsible for 63·03 per cent. of the world's exports.

VIII.—The World's Imports of Manganese-Ores

Let us now turn to the world's import statistics of manganese-ore. They are shown for the same period of five years in Table No. 3. As would be expected the imports by Gondwanaland countries are trivial, amounting only to 0·01 per cent. (by Australia and Argentina combined). The remaining 99·99 per cent. was received by non-Gondwanaland countries, Russia, of course, as the largest producer and exporter, taking none of this; whilst the Axis countries, Germany, Italy, and Japan, took 25·48 per cent. of the imports.

TABLE 3.—*The World's Imports of Manganese-Ore*, 1934 *to* 1938

	Long Tons					
	1934	1935	1936	1937	1938	Mean 1934 to 1938
GONDWANALAND :						
Australia and Argentina .	391	338	172	257	390	309
NON-GONDWANALAND :						
United States . .	341,338	383,500	846,645	974,429	513,637	611,910
France	573,551	366,028	414,687	484,988	314,088	430,668
Germany . . .	221,195	388,029	226,007	545,417	419,060	359,942
United Kingdom . .	202,067	227,605	240,344	283,458	192,376	229,170
Belgium-Luxemburg, E.U.	202,694	235,774	151,848	335,089	193,265	223,734
Japan (*e*) . . .	146,426	209,527	173,956	248,063	145,956	184,786
Norway . . .	106,841	80,078	101,077	128,992	122,543	107,906
Italy (*f*) . . .	64,253	120,313	23,588	74,193	57,162	67,902
Czecho-Slovakia . .	15,809	53,582	53,755	76,486	101,163	60,159
Poland	37,708	62,429	55,810	81,061	62,852	59,972
Canada	27,637	32,840	57,377	68,952	18,795	41,120
Holland . . .	7,277	1,998	8,413	13,565	17,721	9,795
Hong Kong (net imports).	856	358	11,638	21,483	− 884	6,690
Other countries (12) .	19,477	14,896	4,606	4,176	9,448	10,521
Total : Non-Gondwanaland	1,967,129	2,176,957	2,369,751	3,340,352	2,167,182	2,404,275
TOTAL : Gondwanaland + Non-Gondwanaland .	1,967,520	2,177,295	2,369,923	3,340,609	2,167,572	2,404,584

(*e*) Import data not recorded. Figures given are exports from other countries, excluding exports from the Philippines, not available. (*f*) Including manganiferous iron-ore.

IX.—The Atlantic Charter and Absence of Pre-War Handicaps to Axis Countries

The purpose of this conference is to discuss mineral resources in connection with the promises held out by Mr. Roosevelt and Mr. Churchill in the fourth clause of the Atlantic Charter, that :

> 'they will endeavour, with due respect for their existing obligations, to further enjoyment by all States, great or small, victor or vanquished, of access, on equal terms, to the trade and to the raw materials of the world which are necessary for their economic prosperity.'

The statistical data summarised in the three tables accompanying this paper, giving the figures of production, of exports, and of imports of manganese-ore by, from, and to the various countries of the world, show that under the system prevailing prior to the war there was a continuous flow of manganese-ore from the producing to the smelting countries, free of all hindrance, except where import duties had been imposed in order to bolster up a domestic industry, as in the United States,[1] or where the fiscal system had been tampered with, as in Germany (see later).

To illustrate that the pre-war system was not harmful to the Axis countries in particular, and therefore could not provide them with any possible excuse for war, at least in respect of supplies of manganese-ore, the production, export, and import statistics of these three countries for

[1] A duty on imported manganese-ores, except those from Cuba, was imposed in 1922 to help the home industry. The effect in enhancing domestic production was negligible, and the large quantities of manganese-ore needed from abroad for the American steel industry have been continuously imported, but at a correspondingly increased cost to the American steel industry. The American steel producer and consumer have in fact suffered for the trivial benefit of the American producer of manganese-ore. The tariff was reduced in 1936 in favour of ore from Brazil.

the year 1937 are segregated below for comparison with the world's steel production figures for the same year as given in Section VI of this paper above.

The above figures show that whilst the Axis countries appear to suffer from a very grave handicap in that they produce less than 2 per cent. of the world's manganese-ore, yet the system of international commercial interchange in operation prior to the war allowed them to secure 26 per cent. of the world's available exports, or 16 per cent. of the world's total production.

Further, if reference be made to the data of world's production of steel in the same year, 1937, it will be seen that these three countries produced 26,835,442 tons out of a total world output of 132,300,000 tons, or 20·28 per cent. of the total.[1]

In the foregoing analysis I have not taken into account the movements of the ferro-alloys, ferro-manganese and spiegeleisen, made from manganese-ore, for the reason that the total world's exports in 1937 were only of the order of 120,000 tons, by far the larger proportion of these alloys being consumed by the producing countries. Nor have I taken into account the large quantities of manganiferous iron-ores mined and used in the United States of America, nor of manganiferous ores used in Germany and elsewhere on the Continent of Europe so as to decrease the need for imported manganese-ores.

Any handicap that Germany may have felt before the war in securing mineral supplies was due to her own peculiar fiscal subterfuges. Thus I have it on good authority that an attempt to accept an order for Indian manganese-ore shortly before the war was frustrated by Germany's being unwilling to do business except on a barter basis. As a result, in the end, an arrangement was made instead to send South African manganese-ore and raw wool to Germany in return for finished goods such as blankets.

[1] The ratio of weight of manganese-ore secured to that of steel produced—2·86 per cent. for Germany, 5·19 per cent. for Italy, and 5·46 per cent. for Japan—suggests that Italy and Japan were acquiring stocks of ore in excess of current needs.

That Japan suffered no handicap from pre-war international arrangements is shown by the facts that she was allowed to prospect freely in Malaya, and, as a result of the British Colonial policy of equal treatment for nationals of all countries in the territories administered by Britain, Japanese mining companies were allowed to secure mining leases over the mineral deposits discovered, to work these minerals, and to export them in their own ships; even after it was common knowledge that the minerals so won, namely, ores of iron, manganese, and aluminium (bauxite), were being used for the manufacture of armaments that might at any moment be turned to the conquest of Malaya, as has in fact since happened.

The value of these exports to Japan may be judged from the fact that in 1936, the last year for which Japanese data are available, the Malayan exports of iron-ore formed 37 per cent. of Japan's total supplies of this commodity, whilst the Malayan exports of manganese-ore formed 15·6 per cent. of Japan's supplies. The export of bauxite was only beginning in 1936, but by 1939 it had risen to 84,387 tons, which must have formed a substantial proportion of Japan's supplies for that year, with the balance derived mainly from the Netherlands East Indies.

Japan clearly had no grounds for complaint in respect of the administration of mineral policy in Malaya, nor in respect of sanction to grow rubber and oil palms in Malaya.

Looking at the problem as a whole it seems quite clear from the foregoing analysis of results that pre-war arrangements were in every way adequate to enable every country fitted by Nature for the production of iron and steel to obtain by honest trading and purchase at fair rates in the world's markets the supplies of manganese-ore needed.

If, therefore, after the war, international trading can be re-established on a free basis it is quite clear that no special arrangement will be needed for manganese-ores. I anticipate that a statistical analysis of other minerals on the basis of pre-war statistics will lead to a similar conclusion.

If this prove to be the case, then all that Clause 4

Manganese-Ore Statistics, Axis Countries, 1937

	Long Tons			
	Production	Exports	Imports	Available for Consumption
Germany	177	788	545,417	544,806
Italy	33,002	26	74,193	107,169
Japan	70,000	5,562	248,063	312,501
Totals	103,179	6,376	867,673	964,476
World's totals	6,051,312	3,571,374	3,340,609	6,051,312
Percentage of world's totals	1·70	0·18	25·97	15·94

of the Atlantic Charter can mean in respect of minerals is that it is intended to restore pre-war freedom of international trade, breaking down such barriers as existed, such as protective duties against minerals, as in the American case instanced, or hampering barter arrangements, such as were introduced by Germany.

X.—The Necessity of Post-War Rationing of Armaments Minerals

There is, however, one aspect of this subject in which some curtailment of pre-war freedom of flow of minerals will be absolutely necessary; namely, the need after the war to prevent, at least for a period, say at least for one generation, the free passage of minerals and other raw materials of use for armaments to the Axis countries in excess of their requirements for peaceful industrial purposes: in fact, it will be necessary to provide for the rationing of these countries in minerals for a generation or more. For, as Sir Thomas Holland has shown on more than one occasion, the distribution of minerals in the world is such that if the British Commonwealth, the United States, and Russia so decide they can control the armaments' manufacture of possible belligerent countries so as to make it impossible for them ever to go to war again.

This theoretical possibility must no longer be left as a possibility, only to be enforced after war has broken out. It must be used as an active instrument to prevent war. Never again must we permit such a flagrant case to arise as the export of minerals from Malaya to Japan to enable Japan to manufacture armaments to conquer the country from which the minerals were derived.

Lt.-Col. the Hon. Colin Campbell, M.L.A.
Nickel

General.—It is most appropriate that nickel should be included in this discussion of world resources. Almost a rarity a hundred years ago it is now one of the most essential metals for the maintenance of the standard of living at the level now considered necessary in the more advanced countries. Yet at the present time all the nickel used comes from three or four places in the world and 85 per cent. of it is obtained from one small area in Canada. Coming largely from one country and needed by many, nickel forms a useful example of the post-war problem of distribution. This problem in the case of nickel was indeed successfully solved in pre-war years. For a long time nickel has been available to all countries in sufficient quantities to meet all needs at a price which, not being subject to speculation, has remained practically unchanged for many years at a level which has yielded a satisfactory return to the producers and yet has not prevented the metal being readily obtainable for all purposes for which it was needed.

Uses.—Nickel, unlike lead and tin, is rarely used as the unalloyed metal. Its application is principally in alloys, and these alloys, unlike those of, say, copper and aluminium, generally contain much less than 50 per cent. of the metal.

Most of the world's nickel is used in steel. Either alone or in company with chromium, molybdenum, manganese, copper or vanadium and present in amounts of less than 5 per cent., it plays a most important part in producing that wide range of alloy steels which gives engineers the strongest, toughest and most wear-resistant materials available to-day. Without these nickel-containing steels the present-day aero engine would be impossible, as would the huge turbines which provide our electric power and drive our largest ships. The modern automobile and particularly the large commercial vehicles and buses owe much to nickel steels, as do also our present-day locomotives and electric trains. In machines of all kinds wherever strength or durability are required, nickel steels are employed.

Then there are steels in which the nickel content is 8 per cent. or more. These combine strength with remarkable corrosion-resistance and are employed widely in such places as the chemical industry where they have made possible many processes not previously practical, and the food industry where they have contributed largely to present-day standards of cleanliness and quality. These 'stainless steels' as they are called also find many decorative and utility applications in the modern home and public building.

With still higher nickel contents the combination of iron, chromium and nickel provides a range of heat-resisting alloys of considerable industrial and engineering value, while some of the higher nickel alloys, and particularly those where the iron has been entirely replaced, make possible the present-day electric fire, cooker, toaster, hair dryer and other home appliances, as well as the many applications of electric heating in industry.

Distinct from the steels, the carbon-free nickel-iron alloys give exceptionable expansion and magnetic properties. The former properties are being increasingly used for thermostatic control and similar uses, while the latter are essential for present-day tele-communication and have many other applications in electrical and radio engineering. Other alloys containing aluminium and other metals with the nickel make some of the best permanent magnets and are used in our radio loud speakers, in traffic control equipment and dozens of other places.

During the past ten to fifteen years there has been an increase of nickel used in cast iron, and the combination of castability with strength, machinability, hardness and corrosion resistance which are thus obtained justify the addition of this metal to this low priced material. These nickel cast irons are employed in automobile engines, in rolling equipment both for the rolls and the stands supporting them, in large refrigerator units, in Diesel engines, and for a variety of other purposes.

Alloys of nickel with copper combine strength and ease of fabrication with resistance to corrosion by sea water and other media, and are utilised widely in the marine, chemical and other engineering industries as well as in the home for refrigerators, kitchen equipment and other purposes. Some nickel-copper alloys have special electrical resistance properties and are used in instrument manufacture.

When zinc is present with the nickel and copper, the range of alloys known as the 'nickel-silvers'

is obtained. The pleasing silver colour of these alloys leads to their being employed for many decorative purposes, while they form the basis of silver-plated tableware (E.P.N.S.).

The alloys possess useful resistance to corrosion and can be given a special springiness. They are therefore almost universally adopted for carrying the spring contacts on telephone board switches and other electrical connections.

Nickel plays a considerable part in the non-ferrous foundry and nickel bronzes of a variety of types are utilised widely in marine and general engineering. Nickel is also increasingly being used in aluminium alloys, to which it gives especially a degree of high temperature strength which is found of value in aero and other internal combustion engines.

Some nickel is used in the unalloyed form. It has been found to be the best material for the complicated components inside the radio valve. The use of the metal for coating other metals in order to protect them from corrosion is well known and electro-deposited nickel is now generally employed as the basis upon which the popular chromium finish is plated.

Considerable time has been used to describe some of the uses of nickel in order to demonstrate how important is the part that it plays in modern daily life. It is an essential material to any country which wishes to develop the economic prosperity referred to in the Atlantic Charter. If, therefore, such economic prosperity is to be enjoyed it is well to consider from where this nickel is to come.

Sources of Nickel.—It will be clear that in order that an ore can be used commercially as a source of metal certain conditions must be fulfilled. The metal content of the ore must be sufficiently high, the ore must be accessible and mineable, and a process must be available for extracting the metal. The extraction and conveyance of the metal to the market must be at such a cost that will make possible its use. Thus it comes about that, although nickel-containing ores occur widely throughout the world, there are only a few places where the nickel content is high enough, the ore present in sufficient quantity and the chemical combination of the nickel such that it can be extracted economically.

It was for these reasons that, although small amounts of nickel had been obtained from various locations in Europe, it was not until the discovery in the 1870's of nickel deposits in economic quantities in the French island of New Caledonia in the Western Pacific that the supply of metal was at all large.

(a) *New Caledonia.*—The New Caledonian ore, named garnierite after its discoverer, is a hydrated nickel-magnesium silicate ($(NiMg)SiO_2H_2O$). It contains an average of 5–6 per cent. nickel. Mining was commenced in 1875, the ore being shipped to France for recovery of the metal. Later furnaces were erected on the island and the matte obtained by smelting, which contained some 80 per cent. of nickel, was exported instead of the ore. Uses of nickel were not great in those early years and the export from New Caledonia was spasmodic. The indication given by Riley and others in the years around 1889 that nickel conferred special properties on steel led to a revival in the demand, and since that time recovery of nickel from the New Caledonian ores has continued with few interruptions. In the years immediately preceding the present war nickel was being produced from New Caledonia at the rate of 6,000 tons per annum.

The ore deposits in New Caledonia occur near the top of spurs running out from the main mountain ridge which traverses the length of the island. It is located at elevations from 400–2,500 ft., being mostly towards the higher level. Deposits are overlain by soil to depths varying up to 100 ft., and the method of obtaining the ore is to remove the overburden and quarry the ore out.

Various developments have taken place in the smelting methods adopted for treating the ore, but in recent years they have evolved initial smelting with gypsum (hydrated calcium sulphate) and coke in a blast furnace, whereby nickel sulphide matte is produced. This matte is concentrated in convertors and the resulting matte contains some 80 per cent. nickel, the iron having been slagged off. The concentrated matte is roasted to oxidise off the remaining sulphur and the oxide of nickel thus formed is reduced to nickel by heating in contact with carbon. It is understood that the reserves of ore in New Caledonia are still considerable and this should remain a source of nickel for a long time to come.

(b) *Canada.*—Between 1885 and 1890, when New Caledonian nickel was finding its way for the first time in volume to the world's markets, discoveries were being made of nickel-containing ores in the Sudbury district of Northern Ontario, an area which, as indicated already, was afterwards to become the largest source of the metal in the world. It was in 1887 that the presence of nickel in workable quantities was discovered in an ore which up to then had been thought to be a copper-ore. It does contain copper and has provided large quantities of this metal, as well as being one of the world's largest sources of platinum and other platinum type metals.

Nickel was first produced from Sudbury ores in 1888, but the production lagged behind that of New Caledonia until 1900 was passed. Since that time, however, output rapidly increased until just before the present war some 85,000 tons of nickel were being produced each year.

Since the discoveries in the 1880's, numerous deposits have been disclosed around the edge of what has become known as the Sudbury basin. This basin consists of an oyster-shaped area about 36 miles long and 16 miles wide. The ore that is obtained is quite different from that coming from New Caledonia. The main mineral is pyrrhotite (iron sulphide, Fe_8S_9), and with this is associated the copper mineral chalcopyrite ($CuFeS_2$) and the nickel mineral pentlandite ($(NiFe)_{11}S_{10}$). Generally, the nickel and copper minerals are found intimately associated with the pyrrhotite, but in many parts the pentlandite and chalcopyrite may be found concentrated in large masses in a fairly pure condition. The associated rock gangue is predominantly basic.

At the present time several mines are being worked by the two producing Companies operating in this area. These Companies are the International Nickel Company of Canada Ltd.

and the Falconbridge Nickel Mines Ltd. The ore obtained from the various mines differs somewhat in nickel and copper content, but the average analysis runs generally around 3–4 per cent. nickel and copper.

The problem of satisfactorily extracting nickel from the Canadian ores was for many years a source of considerable trouble and worry to the pioneers in both the nickel and copper industries of Canada. It was not until the question of separating the copper from the nickel in the ore was solved, first by Col. Thompson by means of the Orford process, and later by Dr. Ludwig Mond by the process that bears his name, that any real progress was made in either industry.

An important factor in recent years in the treatment of the Sudbury ores has been the development of flotation methods by which considerable concentration of the metal-containing constituents takes place. Concentration is followed by roasting and smelting, whereby the iron and rocky matter associated with the ore are slagged off, while some of the sulphur is removed. The low grade nickel-copper matte thus produced is blown into convertors and the resulting matte is submitted to what is known as the Orford process in order to separate the nickel and copper. The impure copper sulphide thus obtained is sent to the copper refinery, while the impure nickel sulphide is treated either by a process which ends with electrolytic refining or by one ending in what is known as the carbonyl process. The electrolytic refining is carried out in peace time either in Canada by the International Nickel Company of Canada Ltd., or in Norway by Falconbridge Nickel Mines Ltd. The carbonyl process is used by the Mond Nickel Company Ltd., a subsidiary of the International Nickel Company of Canada Ltd., at its works in South Wales.

At the present time the refineries in Norway are in enemy hands and the refining of Falconbridge nickel is carried out by the International Nickel Company. This Company is also treating the matte produced in New Caledonia since the French refinery is also not available.

There are other deposits in Canada, though they are insignificant as compared with those around Sudbury. In British Columbia deposits of ore of similar character to the Sudbury ores have been found and have been worked to some extent. There are also deposits around Hudson Bay, in Saskatchewan, the North-West territories and New Brunswick, but up to the present time none of these deposits has proved of sufficient interest for large-scale development. The proven ore reserve in Canada is in the neighbourhood of 250 million tons.

(c) *U.S.S.R.*—As will no doubt be mentioned in another paper, mining of nickel ore and production of the metal has been going on in the U.S.S.R. for seven or eight years. Both the types of ores mentioned previously are mined, but the quality of the oxide or garnierite type ore is, it is understood, much lower in grade than that mined in New Caledonia. These oxide ores are raised in three areas in the Urals. One area lies to the north-east of Sverdlovsk near Rieje, one is between Sverdlovsk and Cheliabinsk in the Ufalei region, while the third is in the south of the Urals, near Orsk, and comprises the Khalilovo mines and those of Ajermanovka and of the Actuba plateau. It is reported that there are other areas in the Urals in which nickel bearing ores have been prospected but not yet exploited. Some of these lie a considerable distance from transport facilities, and this may be the reason why development has been delayed. These Ural ores are said to have but a low nickel content and are difficult to treat. Nickel, however, is being obtained from them at refineries located near the mines.

There are two other areas where nickel ore is considered to exist in mineable deposits. These areas are the Kola Peninsula or Monche Tundra, and near the estuary of the Yenissei at Norilsk. In both these latter cases the ore is of the sulphide type and is similar to that found in the Sudbury area. Work was proceeding on the Kola deposit before the war, but the present position is unknown.

Lack of information makes it difficult to judge whether the U.S.S.R. will become self-supporting in regard to nickel. Before the war a quantity of nickel was imported annually.

(d) *Finland.*—Within the last ten years the existence of a considerable deposit of nickel ore has been proved in the north of Finland near Petsamo. The ore is of the nickel-copper sulphide type similar to that in the Sudbury area and exploitation of the deposit was begun in 1935. Apart from Canada the Petsamo deposit seems likely to be of material interest to the world. Other deposits have been found in central Finland and it seems likely that this country will provide a definite, though perhaps small, as compared to Canada, percentage of the world's nickel in post-war years.

(e) *Cuba.*—Extensive deposits of nickel-containing ore exist in Cuba, but until quite recently the only interest in them has been in a small production of pig iron containing small percentages of nickel. The ores are of the lateritic type, one analysis published showing about 1 per cent. nickel.

The ore is difficult to treat owing to the presence of chromium, and although much experimentation was apparently carried out in the past no very successful method of obtaining nickel from the ores was devised.

Recently it is understood that two promising methods have been developed and if they prove successful it is anticipated that before the end of the war Cuba will be producing at a useful rate. Whether the island can continue under peace conditions to produce nickel economically cannot be judged from the information at present available, but it can be assumed that if other sources of supply diminish the more than two billion tons of ore said to exist in Cuba will be found to be playing a part in maintaining the world's supply of the metal.

(f) *Brazil.*—Garnierite type ores have been found in various locations in Brazil and some mines have been worked there. The difficulties in this country are largely connected with transport since the mines are in inaccessible places. Much exploration work still needs to be done and a suitable economic process for treating the ores developed. Brazil is not likely to be a large producer of nickel for some years to come.

(g) *Dutch East Indies.*—There are several developed deposits of nickel ore on the island of Celebes in the Netherlands East Indies, and some of these deposits were being worked in the years immediately preceding the present war.

The ores are similar to those of New Caledonia, but are not so rich in nickel.

It is understood that no thoroughly satisfactory process has as yet been applied to these ores, but it is to be expected that in post-war years they will be one of the smaller sources of nickel.

(h) *Greece.*—At Lokris in Greece there is a deposit which has been worked for many years. The ore is in many ways similar to those of New Caledonia, but its lower magnesia content is such as to make it less refractory, while its moisture content is, as a rule, much lower. It contains a small but appreciable percentage of arsenic, whereas there is no trace of this element in the New Caledonia ore. Shipments of this ore were made in pre-war years to Germany and no doubt have been resumed again recently.

(i) *Germany.*—A number of deposits were worked in Germany years ago, but recently there has been only one producing mine at Frankenstein in Silesia and the output latterly has been relatively unimportant. In 1938 reserves at Frankenstein were estimated at 2,500,000 tons of ore containing 1 per cent. nickel, and there is no doubt that this is proving one of the sources of nickel for Germany at the present time. Various new processes for handling these low grade ores have been developed in recent years.

(j) *Norway.*—There are several small deposits in Norway which were worked fairly regularly between 1900 and 1914, refining being completed by an electrolytic process at Kristiansands. During the last war Norwegian production increased to about 900 tons per annum, but it subsequently declined, although in recent years it has supplied larger quantities for the Kristiansands refinery now operated by the Falconbridge Company.

The principal Norwegian ores are not unlike those of Sudbury, but the nickel, copper and sulphur contents are lower than the Canadian ore.

(k) *Other Countries.*—As has been stated previously, small deposits of nickel-containing ore have been found in all parts of the world, but other than those already described none of those reported show at the present time any indication of being large sources of nickel.

A number of deposits have been reported from various parts of the United States, while others have been found in Alaska. Investigation of the Alaskan deposits is continuing at present and it may be that some worthwhile discoveries will be made.

In South America, Chile, Peru, and Bolivia, nickel has been found in association with cobalt, and small amounts of these ores have been mined for their cobalt content. No nickel deposits of any size have as yet been uncovered.

The Japanese have naturally searched diligently for nickel in their own country, and various properties are said to have been developed. Such ores as have been reported are of the garnierite type, but have nickel contents which rarely reach 1 per cent. By means of heavy subsidising nickel has, it is said, been produced from these domestic ores, but the extent of this production is unknown.

Small deposits of nickel-containing ores have been disclosed in various localities in Africa and Australia, while others have been reported in various European countries. None of these ores, however, has as yet justified much development work.

The Post-war Situation.—From what has been said it will be clear that the nickel required by the post-war world will still largely come from Canada. In fact, I would hazard a guess that 80 per cent. will come from Canada during our lifetime. This occurrence throws a particular responsibility on the British Empire in that it will be its duty to see that it is available fairly to all desiring to use for legitimate purposes and yet to prevent its accumulation for war purposes. Post-war prospecting may, of course, disclose valuable new deposits, but there is at present no reason to anticipate that areas comparable with the Sudbury Basin will be uncovered.

On the other hand, there seems little doubt that the demand for nickel will be at least as great after the war as it was in pre-war days. Efforts to reduce the nickel content of some steels and other alloys have been made in past years and are being intensified at present. It appears, however, that nickel will always be required for the higher grade steels and alloys. If, as must be the case, industrial development continues in America, in Great Britain, in Russia, and in the various European countries, they will each require increasing quantities of nickel for those uses which have already been described, and for others which certainly will be developed. Engineers will continue to demand materials capable of withstanding more and more severe conditions, and are likely to turn to nickel alloys to support their requirements.

Then, we must anticipate the development of a higher standard of living throughout the whole of the Far East and when an increased use of aeroplane, automobile, and rail transport, of electric light and of all the other similar amenities which are involved in such a higher standard are required by the millions of India and China, nickel will be needed for those areas to perhaps an even greater extent than it is to-day in Western countries.

Unfortunately, perhaps, nickel, due to the strength, resistance to shock, wear and corrosion which it confers on its alloys, is also a vital war material, and care is therefore necessary to see that in providing nickel for essential peacetime applications it is not utilised by nations with aggressive intent to build up armaments. For this reason, too, since the United Nations will have obligations to maintain peace, sufficient nickel will need to be reserved to them for the provision of the necessary weapons required for the purpose of winning the peace.

You will appreciate that, for purposes of security, I have only been able to use previously published information, and in conclusion I leave these important thoughts with you. (*a*) Nickel has become most important to the maintenance of our standard of living and to the advancement of modern industrial progress. (*b*) The production

for our lifetime is likely to come chiefly from Canada and thus the British Empire. (*c*) Exploitation of other known deposits will almost certainly be possible only at greater cost. (*d*) While important to the peace it is also important to war.

In the time at my disposal I have been able only to place before you a short note on the occurrence and distribution of nickel in the world. They show clearly that the British Empire has in its nickel resources a most important asset to help in the United Nations' task of making and preserving peace. Nickel will always be in demand by all peoples who desire to preserve or improve their standard of living. I again point out that the problem of distribution of nickel was indeed solved in pre-war days by being available to all who desired it and could pay for it. The fair distribution must be on some basis, i.e. area, population or payment, with the odds on payment as the determining factor. To arrange the distribution of the world's mineral resources it may become necessary for the United Nations to make it possible for certain countries to purchase. I merely point this out to show that the problem of distribution is not simply solved by production, demand and transportation. The solution of the problem of distributing fairly nickel and other mineral resources will, as stated in the Atlantic Charter, be of the utmost importance to the peace and stability of the world after the war, and we should be grateful to the British Association for an opportunity in good time of hearing a discussion on this very important issue.

Mr. M. P. Fogarty

Aluminium

THE *Economist* has recently estimated that from 1937 to 1941 the world output of virgin aluminium approximately doubled, reaching just under a million tons, in spite of a fall of about 40,000 tons in Norway, Sweden, Switzerland, and the U.S.S.R. It is reckoned that by the end of 1942 the industry may be able to produce more than a million and three-quarter tons a year, mainly because of large extensions in the United States. Output in the United Kingdom increased in about the same proportion as world output down to the end of 1941, having risen from 19,300 tons in 1937 to about 40,000 in 1941. There is reason to think that it may increase still further.

The increase in the British output of virgin metal does not, of course, indicate anything like the full growth in the output of finished light metal products. The *Metal Bulletin* has estimated the consumption of aluminium in the United Kingdom in 1940 as 135,000 metric tons, against the *Economist's* estimated output of 35,000 tons of virgin metal—the *Metal Bulletin's* figure should be compared with the estimated consumption of 28,400 tons in 1935. More recently, I have been given a rough estimate showing that the total output of light alloys has reached a quarter of a million tons. Imports have risen sharply and scrap is being used more carefully. I have been told, on uncertain authority, that secondary aluminium was being produced in Great Britain early in 1942 at a rate of 44,000 tons a year. I have found no comparable pre-war figure; but the Census of Production records 23,000 tons of scrap and secondary metal among the raw materials of the aluminium trade in 1935, and this may be some guide.

The most immediate question from our point of view is whether Great Britain will be able after the war to absorb either its own increased output of metal, both virgin and secondary, or the still greater increase in its output of light metal products. Will this country be able to absorb part of the aluminium surplus of the areas where the biggest expansion has taken place—particularly Canada, the United States, and Germany—or shall we ourselves have an aluminium surplus to pass on to others, or perhaps be able to do no more than absorb our own output?

The British aluminium industry in the last few years before the war was in an unsatisfactory position. The Census of Production in 1935, the last year before the rearmament demand began, showed that British output of aluminium castings had risen by 47 per cent. since 1930, and of foil by nearly 70 per cent.; the output of plates, sheets, strip, tubes, angles, and similar products had probably risen in about the same proportion as castings, though it cannot be exactly measured. On the other hand, the output of aluminium hollow-ware for domestic use had risen by only 6 per cent., and production of wire had probably fallen, though this cannot be definitely shown; expenditure on the Grid, which absorbed about 12,000 tons of aluminium wire, was at its peak in 1930–4 and by 1935–6 had fallen back almost to the low level of 1929–30. Imports of aluminium manufactures fell off sharply during the depression, and were prevented from recovering by the imposition of a 10 per cent. duty in 1934, and by the new Cartel agreement of 1932, so that to a substantial extent (particularly in the case of plates, sheets, etc. and hollow-ware), the increase in British production merely compensated for the decline of imports. 'Metal Statistics' (*Metallgesellschaft A.G.*) estimates that British consumption of aluminium was actually smaller in 1935 than in 1929, and no more than 4,400 tons—18 per cent.—greater than in 1930. British output of virgin metal had risen slightly, from 13,900 tons in 1929 and 14,000 in 1930 to 15,100 in 1935. For an established industry with relatively inelastic markets the rate of progress of aluminium between 1930 and 1935 would have been satisfactory. For a new and expanding trade it was strikingly inadequate; all the more so by contrast with the aluminium trade's own progress between 1924 and 1930, when, simultaneously with a rapid increase in imports, British output grew decidedly faster than after 1930 and consumption more than doubled.

It is difficult to say what happened to civilian consumption between 1935 and 1939. It was announced in the summer of 1941 that British civilian consumption of aluminium was at a rate of about 2,500 tons a month just before the outbreak of war, or 30,000 tons a year. This compares with a total estimated consumption of 28,400 tons in 1935, when the aircraft industry, the main military consumer, used 2,100 tons, of which a good deal must have gone into civilian aircraft; evidently there was some increase in civilian consumption in 1935–9, but probably at a rate no greater than in 1930–5.

This relatively slow rate of progress was not due to any lack of potential markets. Several important industries, which might have used very large tonnages of aluminium, had made experiments with satisfactory results. On the railways and in road transport aluminium was increasingly used both for such things as containers and in the building of vehicles. Aluminium valued at £1,100,000 was used in the British motor and cycle trades in 1935. The British railways have built a number of railcars mainly of aluminium—the L.M.S. Northern Counties Committee, for instance, built a Diesel car in which the use of aluminium saved ten tons, about a third of the weight of a car of normal construction—and have used increasing quantities of aluminium for window frames, doors, luggage racks, interior fittings and decorations. In several other countries, particularly Scandinavia and the United States, successful experiments were made before 1939 with aluminium passenger coaches, goods wagons carrying chemicals or foodstuffs which might react chemically with wagons of ordinary construction, and even, in some cases, with the use of aluminium for parts of locomotives. Shipbuilders were tending to pay more attention to aluminium, on account of the development of alloys protecting either by anodising or by special finishing, and with high resistance to corrosion. High-silicon aluminium alloys were being used for unstressed parts of ships, such as turbine gear casings and gear covers. Aluminium alloys containing up to 7 per cent. of magnesium were being used to replace brass and gun-metal for deck fittings and similar purposes where high resistance to corrosion is essential, and, in some cases, were also used for structural purposes. In this country, small boats up to 65 feet in length were being built with aluminium alloy hulls.

Apart from transport, which both actually and potentially was the most important market for aluminium, there were a number of interesting possibilities. The 12,000 tons of aluminium wire absorbed by the Grid have been mentioned ; in 1939 electrical conductors took more aluminium in the United States than any other use except transport. Architects were being attracted before the war partly by the light weight of aluminium, but very much also by the possibility of giving it a high polish, and by the fact that anodised aluminium can be dyed any colour and will not perish even under prolonged weathering. The group of trades classed by the Census of Production as ' Mechanical Engineering ' used between 2,500 and 3,000 tons of aluminium in 1935, excluding the amounts used in marine and locomotive engineering. In several industries, such as cotton weaving (the textile machinery trade used 200 tons of aluminium in 1935) progress was being made in the use of aluminium for light machine parts, and, in some cases, it was being used for heavy work ; immediately before the war the Northern Aluminium Co. were using as one of their advertisements a picture of a large Ransome and Rapier excavator in which the use of aluminium had made it possible to increase the capacity of the bucket by two cubic yards. The market for domestic hollow-ware was probably not fully exploited, and the value of the output of aluminium hollow-ware for industrial purposes actually fell from £82,000 in 1930 to £41,000 in 1935.

The aluminium manufacturers were not backward in letting the world know of their products ; ' vigorous and well-directed propaganda,' as one pre-war writer says, ' has done much to ease the situation in the industry.' But neither propaganda nor the existence of large potential markets made it possible to add greatly to aluminium consumption in Great Britain, and the main reason for this seems to have been the industry's price policy. The details of this policy are irrelevant here ; it is only important to note that what held back the growth of aluminium consumption was not a technical factor of any kind, but the voluntary action of the producers. If new ways of using aluminium can be found the chance of a big increase in civilian consumption after the war will certainly be greater : but it should always be kept in mind that pre-war experience suggests that the key factor is price.

Precisely what is going on during the war is, of course, obscure ; but there are some indications. In all the countries where output has expanded, new works and extensions have, of course, been built ; in many cases operating on a large scale, and in all cases incorporating the latest improvements of technique. More economic use is being made of scrap, and wider use is being made of aluminium down to about 98 per cent. purity where formerly 99 per cent. and upwards was specified. Research work has been intensified in the main belligerent countries. In this country, it is being carried on by the Air Ministry, technical organisations, and several large firms ; the Northern Aluminium Company, in particular, is said to be making ' interesting experiments . . . with an eye to the future.' A new Wrought Alloys Development Association was formed at the end of 1941 to provide information about aluminium and magnesium alloys to assist the war effort, and to advise industry on the use of these alloys in peace-time.

Experiments aimed at securing stronger alloys have been made in several countries ; American experts are trying to get away from the duralumin series, while the Germans are specialising in silicon and magnesium alloys. The report of the *Vereinigte Aluminium Werke A.G.* for 1940 mentioned that new fields of application for aluminium were being opened up in the chemical and engineering trades, and that improvements in surface qualities were opening up new fields in interior decoration, foodstuff packing and electrical engineering. Aluminium was being substituted for lead in armouring cables installed in buildings, and laminated aluminium was being used for switches and electro-chemical purposes. Progress had been made in using oxidised aluminium wires instead of insulated copper. The same report mentioned that pulleys for V-belt drives were being made of aluminium faced with steel, and that their lightness made possible an important increase in speed. Valves are now being made of aluminium alloy, the valve seats being plated with chromium. Progress has been made in developing an aluminium chain, though results at the time of the report were not entirely satisfactory ; aluminium screws are being pro-

duced with threads rolled instead of cut ; and new welding methods have been developed. Improvements in welding technique are also mentioned in this country and America. American producers have made progress in controlling the quality of aluminium castings and other products by the use of X-rays or similar methods, and this is said to have led to increased use of aluminium castings even in aircraft production, where aluminium already held a large share of the market. A new method of mass-producing forged aluminium cylinder heads was announced in May, 1942 : it is claimed that it gives considerably greater strength than casting for less weight, and saves labour and scrap. British research has led to a number of other advances. Explosive aluminium rivets have been evolved, in which a charge of high explosive inside the rivet takes the place of the riveting hammer. Gravity and pressure die casting have been improved, which will prove specially valuable if quantity production is needed after the war. Experience in providing large components for flying boats has led to an improvement in the technique of extrusion, which should very much reduce the cost of large extruded sections after the war. Machining qualities have been intensively investigated and (again very largely in connection with flying boats) the resistance to corrosion of some standard materials has been increased. Finally, the designing departments of the big firms have not been idle. The Aluminium Union ran a series of advertisements in the summer of 1941 showing new designs for stoves, office furniture, kitchen cupboards and tables, and electric cookers, and the Northern Aluminium Co. have advertised, among other things, the possible uses of aluminium in ship designing. At least one other firm is known to be actively investigating possible uses of aluminium alloys in building. The railways, which are among the biggest potential consumers, are also experimenting.

It goes without saying that many of the improvements in technique and the new products which have been developed have not been mentioned in public. But enough is known to show that considerable progress has been made both in discovering new fields where aluminium might be applied and in improving the technique of manufacture. There is something to be said on the other side ; the practical withdrawal of aluminium from civilian use has checked development in some fields, such as road transport or hollow-ware, and, in a few cases, substitute materials have proved so satisfactory as to be likely to be retained permanently. In some uses, even in munition trades, aluminium has been superseded ; early in 1940 the Air Ministry circularised aircraft manufacturers asking them to use plastics instead of aluminium alloys, mainly in unstressed parts, such as air ducts, scoops, wheel spats, ammunition chutes and dinghy boxes. But these setbacks are probably more than balanced by the increased popular interest in aluminium due to the war.

A more important point is that it seems likely that much more use will be made of corrosion-resisting iron and steel after the war than before it. From the point of view of technique, aluminium and corrosion-resisting iron and steel are directly competitive in a number of uses ; which brings us back to the main lesson of pre-war experience, that the crucial question is price. The British price of aluminium is still £16 above the pre-war level : but this is hardly a reliable guide to post-war possibilities. A better indication is the fact that American prices have been cut 25 per cent. since the outbreak of war. The main technical obstacle to a comparable reduction in prices here after the war seems to be high power costs. American reduction plants before the war were built in areas where hydro-electric power could be generated for less than 3 mils a unit, which represents about 0·15 pence at the 1937-8 rate of exchange and 0·18 pence at the present rate. The highest power cost at which European plants were reckoned to be able to operate economically before the war is said to have been about 0·8 gold pfennigs a unit, about 0·15 pence at the 1937-8 rate of exchange—the same figure as in America. The British Aluminium Company's subsidiary, the Lochaber Power Company, which has a modern hydro-electric plant, was selling power in 1937 at an average rate of 0·26 pence a unit. At this rate, the power needed to make a ton of aluminium would cost about £29 against £17 (at the 1937 rate of exchange) with power at 3 mils a unit. This differential of £12 a ton (13 per cent. of the pre-war price) might not be impossible to remove ; during the debate on the Caledonian Power Bill in 1938 Sir Thomas Inskip stated that electricity could be generated by water power at Corpach for 0·12 pence a unit, and at Port Talbot by steam for 0·165 pence. There is reason to think that some progress has been made towards this end in the new stations and extensions built to supply light metal industries during or just before the war, particularly in South Wales. It has been proposed that after the war there might be established one or more power industrial estates—specialised trading estates on which electro-chemical and electro-metallurgical industries could be grouped round a power station in such a way as to minimise power costs. The suggestion of an estate in South Wales was examined and rejected some time ago by the Central Electricity Board, and it is not certain whether it is worth reviving : it is, at least, worth bearing in mind.

Apart from such technical factors as power costs, the price of aluminium after the war depends on the policy of manufacturers and of any Government control which may be retained, and this policy is, of course, uncertain. However, there is no doubt that British experts do expect a heavy fall, and there is some guarantee of this in the fact that American prices have fallen sharply during the war and are expected to go down still further. Having this in mind, several experts have expressed the view that it should be possible after the war to absorb the whole British output, apparently including the output of secondary aluminium. There may be some difficulty immediately after the war, when the supply of aluminium scrap will presumably be very large indeed, even after allowance has been made for the aluminium which has been used for incendiaries, metallurgy and other purposes from which it cannot be recovered. But, corresponding to the large supply, there will be a very large sup-

pressed demand for aluminium for civilian transport, hollow-ware, machinery for civil industry and other types of goods of which the output has been restricted during the war, and for which the supply of aluminium, in particular, has been almost entirely cut off. The lack of shipping immediately after the war may make it desirable for a time to restrict imports of bauxite and, therefore, output of virgin aluminium, and in the probable state of demand for aluminium goods stocks of secondary aluminium should be rapidly eaten away. Beyond this first period, it is obviously impossible to make any definite prediction ; it can only be said, as a very wide approximation, that if the relative price of aluminium is cut in this country as vigorously as it has been and may be in America, it should be possible to use, at any rate, the greater part of the present output.

It is greatly to be hoped that this will in fact occur, since there is very much more at issue than simply the prosperity of those immediately concerned with aluminium. In view of the large aluminium surplus which may arise in countries such as Canada, the United States and Germany, any action which tends to restrict consumption may have an unfortunate effect on international relations, even if agreement is obtained between the producers concerned through a new cartel. It is also important for solving our own export problem that a large supply of cheap aluminium should be available. Aluminium exports were not themselves very important before the war—about £1¼ millions worth of aluminium goods were exported in 1937—and the very large world supply of aluminium after the war will probably prevent a rapid increase in our sales abroad ; but the part which aluminium may play in lowering the cost and improving the efficiency of transport services, containers and, in some cases, machinery, may prove to be very important indeed. And, thirdly, it is important for some of the former depressed areas that aluminium output should be maintained or, at least, that any contraction should be very carefully planned in the light of the needs of these areas. Several of the chief new reduction and manufacturing works are in former depressed districts, such as South and West Wales and Cumberland, and it is desirable that these works should be kept going—if there must be contraction in the aluminium industry, it would be best if it could take place elsewhere. On the other hand, though it is impossible to estimate accurately what metals would be displaced if the quantity of aluminium consumed were permanently increased, one of the metals mainly concerned will certainly be steel, which is a product largely of the areas most liable to depression. More detailed examination would be needed to decide how far the advantages and disadvantages to the possibly depressed areas of increased aluminium production balance each other out ; it is enough here to recognise that there is a *prima facie* case for trying to increase or, at least, maintain output so far as possible in certain areas, and a very strong case for planning the development of aluminium after the war so as to gain the advantages of increased employment while, so far as possible, avoiding dislocation in competing trades.

Mr. Julius L. F. Vogel
Tungsten

THE fact that it is only about forty-eight hours since I received a request to prepare a paper for this Conference is, I hope, sufficient excuse for my remarks being brief, and based on information not fully up to date.

Except for the title of the Conference, I have had no guide as to the way in which I should deal with the subject. It seems to me, however, desirable to put the cart before the horse by outlining briefly the uses to which tungsten is put and the way in which the metal is prepared for such uses.

The first practical application of tungsten dates back to about 1860 when Mushet added some tungsten ore to tool steel he was melting, and by reduction of the tungsten trioxide in the crucible obtained steel containing from 2 to 5 or 6 per cent. of tungsten. This was found to have noticeably improved qualities.

For a number of years the demand for such steel, which was only slightly superior to the best carbon tool steel, did not improve materially. The reasons were probably that defensive armour and projectiles had not yet reached a degree of hardness which called for still harder tools, and further, machine tools then existing were not strong enough to utilise Mushet steel to the best advantage. However, the race between armour and projectiles went on and eventually reached a stage when even the best carbon tool steel could not be utilised effectively either for the depth of the cut or for the speed of cutting.

At the speed of working needed for commercial production great heat is generated at the tool tips, and these rapidly soften and need grinding, hardening and re-tempering. Sheffield was not slow to apply the use of tungsten to meet these conditions, but a noticeable landmark is to be found in the demonstration of high speed machine cutting by the Taylor White Steel in the Paris Exhibition of 1901. From that date onwards, high speed tool steel grew steadily in demand and the technique of its manufacture, with increased percentages of tungsten up to 18 to 20 per cent., was developed in many places, and especially in Sheffield.

For the original low percentage the addition of raw tungsten ore sufficed, but to add the increasing quantities it was found essential to employ metallic tungsten either as pure, or nearly pure metal, or in the form of an iron tungsten alloy.

Up to the date of the 1914 war, Germany had a stranglehold on the tungsten industry, and British steel makers imported all their requirements in the form of 96–98 per cent. tungsten metal powder. War conditions entailed production in England and several factories were started, including one owned by some thirty high speed steel makers collectively, and the output of this factory alone reached 80,000 lbs. a week of 98–99 per cent. tungsten by the end of the war.

There were six or seven other factories, but post-war conditions resulted in the practical cessation of demand for a considerable time and only four makers, two on a large scale and two much smaller, survived the slump.

To make the picture complete in respect of the

use of tungsten, the present position must be referred to briefly.

The best quality high-speed steel contains some 18 per cent. tungsten, together with some chromium and vanadium. This is more or less a standard quality. Still better results are obtained by adding in addition, cobalt and molybdenum. With such steels, modified in accord with steelmakers' experience, high rate of cutting and deep cuts which bring the tool tip to a visible red heat can be employed, as tungsten steel has the property of maintaining its hardness at high temperatures.

It has been known for many years that part of the tungsten can be replaced by molybdenum with more or less equal results, and use is being made of this in view of the present shortage of tungsten. A further advance has been made, however, in utilising tungsten carbide containing about 6 per cent. carbon with cobalt (as a binder). The technique in this case differs altogether from that employed for high-speed steel. Instead of melting the ingredients in crucibles or high frequency furnaces, carbide tool tips are prepared by intimately mixing the materials in the form of impalpably fine powder, compressing into the desired form under pressures of many tons and sintering at carefully regulated high temperatures in a neutral atmosphere. The tips so formed are then welded electrically on to the shanks of high tensile steel.

Having thus given an outline sketch of the cart, before I proceed to the horse I must very briefly speak of the harness, that is, the preparation of tungsten in suitable form for use in steel from the raw materials, tungsten bearing minerals.

The process of manufacture can be divided into two distinct parts. For producing tungsten metal powder and tungsten carbide it is necessary to separate the tungsten trioxide in the minerals from all other ingredients. The extent to which the tungsten trioxide must be refined differs according to the use to which it is to be put. For inclusion in molten high speed steel a product of 98/99 per cent. purity suffices, provided certain deleterious impurities are kept below definite limits.

For carbides and for tungsten filaments and rods, the oxide must be of the highest purity with an assay of over 99·9 per cent. tungsten trioxide. To attain this end the mineral must be treated chemically either by attack by soda or by strong acid. The various steps in the processes must be carried out with great care to ensure the requisite purity of the products, and to minimise the loss of tungsten in the operations.

The second method of obtaining tungsten in a form capable of being incorporated in molten steel is by reducing the tungsten trioxide in the mineral either by carbon in electric furnaces or by alumino-thermic methods in admixture with sufficient iron to yield ferro-tungsten containing 80/85 per cent. tungsten. In this case the mineral employed must be within a certain standard of purity, especially in respect of other metals, such as tin and copper, sulphur, phosphorus and arsenic. In electric furnace production tin can be boiled off substantially, but in using alumino-thermic reduction this metal must be present only to a very small extent.

The extremely high melting point of tungsten metal involves its production as powder, but ferro-tungsten fuses into solid form and must be broken up and crushed to small lumps or powder, as specified by various steel makers.

Turning now to the origin and production of the ores of tungsten, there are two distinct classes. The most plentiful by far is known by the name of wolfram, and consists of tungstates of iron and manganese in varying proportions. Academically, distinction is made between ores high in iron and those high in manganese. The former are known as ferberites and the latter as hubnerites, but commercially, both sub-divisions are included together as wolfram.

The second class is scheelite, a tungstate of lime. I do not profess to have sufficient knowledge to discuss the geological origin of tungsten ore deposits. It is common knowledge that they are found almost entirely in close contact with tin ore, both *in situ* and in detritus deposits, and as I understand, there is still, as I know there was a few years ago, strong difference of opinion between geologists as to which mineral was first deposited from the mineralised solutions which apparently carried them into the fissures to form quartz lodes.

I have been shown specimens which appear to substantiate both theories, but as my work has been confined to separating the two metals for recovery of each in a pure state, I have not been interested to attempt to deduce how and why Nature has mixed them up to a greater or less degree.

It is noticeable, however, that lodes and alluvial deposits of each mineral in an almost pure state exist in close proximity to one another.

When I was first interested in the manufacture of tungsten, some forty-five to fifty years ago, the chief sources of supply of the minerals were Portugal and Spain, Cornwall, Australia and Bolivia. As the demand grew fresh discoveries were made and from about 1905 Burma became a producer and by 1914 it was giving the largest output. The war then increased the demand enormously, and widespread search for new deposits followed. It was not long before China came into the picture, and very soon dominated production, although U.S.A. began to obtain a substantial output, though at high cost. Bolivia, Malaya, New Zealand, also developed known and new deposits.

The intensive demand was met to the best advantage from alluvial deposits, of which China especially had very large areas.

An interesting feature of wolfram production is to be found in Cornwall. In the middle of the nineteenth century when innumerable Cornish mines were producing copper and tin, many wolfram lodes were met, but the mineral being then of no commercial value the product was dumped, if sufficient tin could be obtained at the same time to pay, or the wolfram deposits were left entirely alone.

Examination of old dumps and search of old records are in progress and already have achieved some success in developing increased supplies of wolfram from Cornwall so urgently needed now that our Burma supply has been cut off and export from China is stopped.

A feature of wolfram lode mining is the patchy nature of the deposits. Well-defined lodes have zones carrying good values, and then completely barren quartz may extend for a considerable distance. The nature of the lode mines of wolfram is such that no reputable mining engineer can, or will, estimate the yield over any extended length or depth, and bulk sampling alone is a true guide.

In respect of alluvial deposits, drilling and then close pitting will give fairly accurate data and will enable work to be planned ahead.

All tungsten ores are extremely heavy and their separation from gangue by water is efficient, but not from tin ore, the weight of which approximates to that of wolfram.

However, separation of these two minerals can be effected by magnetic machines, as wolfram is feebly magnetic, while tin ore and gangue are not. Concentrates obtained in this way assay from 65 to 70 per cent. tungsten trioxide, or, in round figures, 2 tons of concentrates will yield 1 ton of tungsten.

I must again apologise for the sketchy nature of the information I give in this paper and for the absence of statistics, assays and other data, which need more time than I have had to collect and arrange.

In conclusion, I would point out that while the output of tungsten ores at the maximum of some 30,000 tons a year is insignificant in comparison with that of copper, tin, zinc and other metals, every ton of tungsten is equivalent to 5 to 25 tons of steel in one shape or another, the whole of which is essential not only for our war effort, but for all means of rapid transport and modern engineering in time of peace. Its application and use is no bad example of the contribution of scientific metallurgy to the engineering industry.

Discussion

Sir Harry Lindsay (Director of the Imperial Institute) explained that he was not himself a scientist and therefore could not presume to comment on any of the papers which had been read that afternoon. He did, however, claim to be something of an economist—as, indeed, all thinking people must be under the stress of war conditions. He pointed out that although the fourth clause of the Atlantic Charter had emphasised that the Governments of the United Kingdom and the U.S.A. would endeavour to secure for all States access on equal terms to the raw materials of the world, several of the papers read during both morning and afternoon sessions had warned the audience of the dangers inherent in so free a policy so far, at any rate, as concerned minerals contributory to munitions production. Presumably, the authors of the Atlantic Charter considered that this point was safeguarded by the terms of the eighth clause providing for disarmament of aggressive nations. In this connection his mind went back to the years following the war of 1914–18. It happened that he himself, as Indian Trade Commissioner, had had a good deal to do with several of the minerals forming the subjects of the afternoon's papers. He could not forget how disappointed had been the wolfram producers of Burma when control of tungsten prices had been removed; or the effect of the Russian manganese price policy on Indian production. The World Economic Conference of 1933 had stressed the importance of certain schemes of international control of staple commodities of which the subsequent control of tin had been definitely successful. Nickel also was an example of a wisely controlled mineral. He expressed the hope that the policy of 'Controls' would not be lightly discarded at the conclusion of the war.

Saturday, July 25: Morning Session

Address by
Dr. C. H. Desch, F.R.S.
Chairman

In the course of the Conference held by the Association last autumn attention was drawn to the enormous increase in the production of the most important metals, the output doubling itself in quite a short period: 12 years for copper, 17 for pig iron, 18 for tin, and so on. Along with this quantitative growth the development of modern industry has brought with it remarkable qualitative changes, elements which until lately were curiosities of the laboratory rising into industrial importance. Aluminium, which seventy-five years ago had only been obtained in quantities of a few pounds, had a world production at the beginning of the war approaching a million tons, whilst its later development on both sides of the Atlantic has been on a very large scale. Aluminium is not one of the rare metals, it is in fact the most abundant of all metals in the earth's crust, but at present bauxite, a rich mineral of very local distribution, is alone used for its extraction. But elements of rare occurrence, such as tungsten, molybdenum, and vanadium, now occupy, in consequence of the ever-increasing demands of the engineering industries for materials of higher strength or other special properties, a key position out of all proportion to their abundance. This is largely due to the discovery that the properties of a metal may be profoundly altered by very small additions of another element, metal or non-metal. Pure iron is even softer than copper, but less than 1 per cent. of carbon converts it into steel which may be made so hard as to scratch glass. This fact had been discovered empirically many centuries ago, but now that the process is better understood there are many other instances of the same kind. The importance of alloying elements in steel is being dealt with by Dr. Hatfield, but the principle is by no means confined to steel. Copper can be made hard enough to serve as springs and even as non-sparking mining tools by adding 2·5 per cent. of beryllium, whilst the soft metal lead may be strengthened, so as to offer a greater resistance to frost when used for water pipes, by alloying with so little as 0·05 per

cent. of tellurium. These and similar observations have led to important developments in metallurgy, depending on the use of comparatively rare metals, which are mostly found only in local concentrations in various parts of the earth. In a statistical table the production of some of the minerals from which these rare elements are obtained may not seem impressive, but the access to them may be an important factor in the capacity of a country to produce machinery and other constructions into which metals enter.

The usefulness of the less common metals is of course not confined to small additions. The possible combinations of metals with one another are virtually infinite, and in spite of the vast amount of research and practical experience in this field there must be many valuable combinations as yet undiscovered. The first recognition, partly accidental, that steel could be made to resist corrosion by incorporating 14 per cent. or so of chromium led to the development of the important class of stainless steels, whilst the new magnet steels, containing aluminium and nickel, and in their later forms also cobalt and copper, have brought about a revolution in the construction of electrical instruments and loud-speakers, the very high magnetic concentration which is possible with them enabling very small permanent magnets to be used. For other purposes, such as the clutches used for holding work in milling and grinding machines, they replace electromagnets. With these steels it is possible to realise the image of Mahomet's coffin, heavy bars floating in the air in consequence of their strong magnetic repulsion.

A few of the rarer metals find applications depending on their own peculiar properties. Thus tungsten, with its very high melting point of 3650° C., has superseded all other materials for the filaments of electric lamps. The invention of the fountain pen called for an exceedingly hard and incorrodible substance for the tips of the gold nibs, and this was found in a native alloy of osmium and iridium. Tantalum has proved specially suitable for the spinnerets used in making artificial silk, rhodium and indium for depositing in thin layers on other metals for protection against corrosion, and so on. The non-metal selenium is used in photo-electric cells. Further uses of this kind will present themselves as the properties of the less common elements are studied more completely.

The high melting point of some of the metals has led to research in two main directions. On the one hand it has been necessary to devise means of making metals compact and strong without melting them, and on the other to develop new materials and new techniques for operations at temperatures higher than those in ordinary metallurgical furnaces. Tungsten cannot be melted in a container of any known refractory material. The powder obtained by reducing its oxide is therefore packed into the form of bars under pressure and heated electrically until the particles cohere, and is then hammered in a special way until its strength is sufficient to allow of it being forged or drawn into wire. The same process has been applied to other metals, and a new branch of technology, known as 'powder metallurgy,' has grown up. Not only the metals of high melting point, but copper, bronze, and even the low-melting alloys of tin, are prepared in the form of small particles and made to cohere by heat and pressure. The method has several advantages. Small objects may be produced of accurate shape, requiring no machining, by pressing in dies, whilst the mass may be made completely solid or given any required degree of porosity. Such porous masses are particularly useful for bearing metals, the spongy metal holding the lubricant better than by any arrangement of grooves. The method of consolidating a powder is also used in the making of carbide tools. Certain very hard compounds, especially the carbides of tungsten and titanium, which for many purposes can replace diamonds, are brittle in the mass, but if crushed and mixed with a metallic powder, mainly cobalt, and then heated until perfect union with the binding material is brought about, yield a composite mass which is excellent for tools and dies.

The chief obstacle to chemical operations at very high temperatures, 1600° C. or over, lies in the difficulty of finding materials for furnace construction and for containing vessels which are both strong and resistant to chemical attack at such temperatures. The ordinary fireclays become soft and are attacked by slags. A few oxides, especially alumina, magnesia, thoria, and beryllia, meet severe requirements in this field, but their refractory qualities are lessened by quite small proportions of impurity, and their preparation calls for special technique, which has been developed as a result of long research in the laboratory, but has as yet been little applied on a large scale. When such materials become available in quantity—and there is no difficulty in principle, although the procedure may be costly—we shall see important developments in chemistry and metallurgy at high temperatures. It is interesting to note that it is the oxides of some of the rarer elements—thorium, beryllium and zirconium—which have the highest softening points among the refractory materials, so that their importance will grow with the extension of high-temperature processes.

In the heating of metals or other conductors it is not necessary that the heat should pass through the walls of the containing vessel, as it does when a metal is melted in a crucible furnace. Modern heating by induced currents of high frequency allows the heat to be generated where it is required, that is, within the mass to be heated. This involves a less severe tax on the refractory materials, and also makes it possible to enclose the charge in an outer closed vessel which remains cold, so that the operation can be carried out in a high vacuum or in an atmosphere of some inert gas. This is not merely a laboratory device, but is used on a large scale in a number of manufacturing operations, which will become more numerous in the future. Melting in a vacuum, out of contact with furnace gases, gives a means of preparing many substances in a state of great purity and soundness, unobtainable in other ways, and is already applied to certain alloys in amounts of several tons at a time.

Many chemical reactions are made possible or are accelerated by high pressures. The auto-

clave has long been a familiar piece of chemical plant, but some of the processes for the production of ammonia from the air or for the hydrogenation of coal to form oils and petrol called for higher pressures than those of the usual autoclave, and recent work, especially in America, has shown the remarkable results which may be obtained under pressures of many thousands of atmospheres. To construct vessels to be operated at such pressures, sometimes combined with high temperatures, naturally involves entirely new engineering methods. The materials used are mainly steels, although hard carbides may have to be used for certain parts, but for the highest pressures counterbalancing stresses have to be applied by shrinking one cylinder over another or in various ways producing an internal stress opposite to that which will arise in operation. Here is another new branch of engineering of great scientific interest, extending the range of usefulness of known materials.

The substitution of one metal for another for particular purposes is not always due to inherent advantages, but is often a consequence of a policy of self-sufficiency adopted by an industrial country. This motive has been very prominent in recent years. It is natural that Germany, producing much aluminium but very little copper, should adopt the lighter metal for overhead electric power cables, but a similar replacement in the windings of motors and dynamos was purely due to conditions of blockade and could not be defended on other grounds. During the period of armament and of hostilities such substitutions have been very numerous, but the subject is too big to be entered on here. A few instances of substitution under normal conditions may be mentioned. The saving of weight by using light alloys of aluminium or magnesium in place of steel has mainly been utilised in aircraft and rolling stock construction, but it has occasionally been applied in ordinary structural work. A bridge in Pittsburgh, having been condemned as insufficiently strong for the increased traffic, was lightened by replacing the wrought iron road girders and floor by aluminium alloy. The main girders were still in good condition, and the lightening of the dead load gave the bridge a new lease of life.

The substitution of one material for another is not, as a rule, a simple matter. Metals differ not only in strength but in elastic properties, and this difference has to be allowed for. The new Quebec Bridge was designed to take advantage of the high tensile strength of nickel steel, the designers considering that the Forth Bridge, a very stable structure, was unnecessarily heavy. The disaster of 1907, when the unfinished bridge collapsed, was due to the crumpling of the lower members, although calculation had shown that the direct load-carrying capacity was ample. It has been proposed to use alloys of aluminium on a large scale in shipbuilding, their use in small vessels having proved successful, whilst the particular alloys used, those with magnesium, are highly resistant to corrosion by sea water. In changing from steel to light alloy, however, it would not be enough to calculate the dimensions of each member to give a strength equal to that in a steel ship. The hull would float too high in the water, whilst problems of stiffness would arise from the very different elastic properties, and to build a successful vessel the design would have to be new from the beginning.

So, when the hard carbide tools were introduced to take the place of tool steels for very heavy work or large output, allowing cuts to be made on a lathe at much higher speeds than before, advantage of the improved properties could not be taken until the machines themselves had been completely redesigned to allow of such high speeds without undue vibration, and in fact the introduction of carbide tools has meant a revolution in the machine tool industry, much plant intended for large outputs being rendered obsolete.

Three instances may be given of the substitution of an entirely new material for one of which the supplies have been found to be inadequate or too costly. Platinum, a metal of very local occurrence, has been largely replaced for chemical purposes, fused silica taking its place in the concentration of sulphuric acid, and iron oxide in various catalytic processes. On a larger scale, Chile nitrate, a product formed under quite exceptional climatic conditions and almost unique, is no longer indispensable as a fertiliser, the nitrogen compounds required for agriculture and explosives being obtained synthetically from the air. The third example is the introduction of plastics, resin-like substances which may be given the most varied properties. For many purposes they replace metals, and when reinforced by textile material or paper have a strength comparable with that of a metal. Transparent varieties replace glass and are far less brittle; other types take the place of porcelain and earthenware. The manufacture of plastics is one of the most rapidly growing industries, and the uses of these new materials are continually being multiplied.

It must be realised that even such substitutions as these do not necessarily lessen our dependence on mineral resources, although the relative importance of different deposits may be altered. Nitrogen compounds are obtained by the use of electric power, which in some countries is derived from water, but in some of the most highly industrialised countries has to come from the combustion of coal. Many of the plastics are also derived from coal or petroleum, but, being organic compounds, there is always the possibility of producing them from vegetable matter, as, for instance, through the production of alcohol by fermentation and its conversion into more complex compounds. Such a procedure would be in line with the policy mentioned at the September conference, of depending on current revenue, derived from plants, rather than drawing unnecessarily on mineral capital, which once exhausted is not replaced.

Much might be said of means of economising metals—the use of structures built up by welding in place of heavy castings; the combination of concrete with steel in buildings and bridges; the saving of valuable metals by employing them as thin coatings on mild steel in chemical plant, and so on, but time does not permit. As new materials come into use and new techniques are developed, while at the same time the known reserves of

some indispensable metals are being depleted, it becomes clear that the efficient use of the world's mineral resources demands systematic planning. First of all, a far more thorough world survey is needed, gathering together the information collected by prospectors in the interest of large industrial corporations as well as by the various national surveys. This survey would form the basis of a system of international control, and it is to be hoped that suggestions as to how this may come about will be one of the results of this conference.

Dr. E. F. Armstrong, F.R.S.
Minerals, Old and New, from the Sea

HAD I been writing a book on the subject I should have first described the crust of the earth, some 20 miles in thickness, and then gone on to point out how, by the processes of destruction and denudation, this is continually being washed first into the rivers and finally into the sea, much of it going into solution. As the poets tell us ' even the weariest river winds somewhere safe to sea.' The quantity of any one constituent of the crust in a thousand parts of sea water is infinitely small and indeed many are only detectable by the most refined methods of the chemist, but there is so much ocean in the world that in the aggregate it contains many tens of thousands of tons of even the very rarest constituent.

In the past, but for one constituent—common salt—sea water has never been regarded as a source of raw materials for industry. To-day three other essential substances, potash, bromine, and magnesium salts, are being extracted in considerable quantity from the sea by methods which are both novel and interesting. Such methods open up an avenue to the winning of other even scarcer but coveted minerals.

Common salt is an essential for both man and beast and those countries which lack it go to any end to obtain it. In New Guinea, for example, it was used by traders not so long ago as the best currency for the purchase of native goods. In Britain and in Europe there are large deposits of pure salt resulting from the drying up of inland seas in past geological ages. The Dead Sea in Palestine is an example of such a sea in process of evaporation. At Stassfurt in Germany the sea dried up entirely, so that both the salt and the mixture of potassium and magnesium chlorides, sulphates and bromides remain in the earth, though strange to say there is no iodine.

The composition of the ocean varies considerably in different places and at different depths.

The salinity expressed as total salts per 1,000 parts of sea-water varies from a minimum in the southern part of the Indian Ocean, 33·01 parts, to a maximum from the middle of the North Atlantic, 37·37 parts.

In hot countries the sea is led into basins and allowed to evaporate in the heat of the sun until first the calcium sulphate and then the salt crystallises : the salt is impure but suffices. The bittern or residue is of no commercial value though it has been further treated to obtain potash in an Italian colony.

The export of salt from England has for long been a significant part of our overseas trade. Together with the chemical products made from it, for salt is one of the foundations of chemical industry, it has helped to make Liverpool one of the world's greatest ports.

The exploitation of any particular source of a mineral is determined by economic considerations. Bromine affords a good example : so long as the demands for it was relatively small the Stassfurt monopoly maintained it at a high price. When it was required in very large amount to make ' ethyl ' other cheaper sources had to be found.

One of these is the Dead Sea, which is a partially evaporated inland sea situated in a climate where at certain times of the year there is more evaporation than precipitation. Over a long term of years the level of the Dead Sea was constant. It rose, however, during the period from 1890 to 1929, since when it has been falling.

For some years now the Palestine Potash Company has been manufacturing salts of potassium and magnesium, and also bromine from the waters of the lake, the evaporation being carried out in flat pans with the heat of the sun. The Company has worked out a scientifically controlled process based on a study of the solubility and the order of deposition of the various salts in the mixture.

As the concentration of salts at the bottom of the lake is greater than that at the surface the solution is pumped from a depth of 175 ft. It is practically saturated with sodium chloride and begins to crystallise when exposed in the pans. A further concentration by evaporation is effected until the brine is in equilibrium with carnallite.

At the appropriate point as determined by the measurement of specific gravity the solution is pumped to a second pan, and at a later stage to a third pan, in which the highest concentration of potash salts is obtained : floating suction dredges are used to collect the carnallite as it separates. In a final pan the magnesium salts are deposited and the residue is passed through the bromine factory, where bromine is extracted by treatment with chlorine and sodium. The final brine is discarded into the sea.

Fuel oil is the only imported material, the three main raw materials—the waters of the Dead Sea, the sun and the fresh waters of the Jordan—are available on the spot.

The factory affords an outstanding example of the application of chemical science and engineering to practice and constitutes an important British Empire source of these particular minerals.

The Americans went to the sea itself for their bromine, having devised a simple method to extract the traces of bromine from very large quantities of water. At first they fitted up a ship as a floating chemical factory so as to ensure new water all the time. Later the factory was put on land, the effluent water being run to the other side of an isthmus so that it never mixes with the untreated incoming water.

It requires 4,000 gallons of sea-water to yield a pound of bromine, so that a factory making only 50 million pounds, i.e. 25 thousand tons, a year, has to pump a great deal of the sea through its apparatus. The sea-water is made of a particular acidity, the right amount of chlorine gas added and the free bromine so liberated is blown out by a stream of air counter current to the water which is falling down high towers with

wooden packing. It is absorbed in soda solution, forming bromides and bromates. The process is continuous and automatic, and under instrumental control : it is one of the triumphs of modern chemical engineering design and construction.

Though in practice the recovery of magnesium metal from sea water involves comparatively simple operations it is far from being an easy task economically to utilise a raw material which contains about 1 part of magnesium in 800 of water. Quite unusual chemical engineering methods, equipment and control have to be invented.

At the most successful and largest plant use is made of milk of lime, made from large deposits of fossil oyster shells found in the vicinity, to precipitate magnesium hydroxide from sea water which has been freed from extraneous matter. The hydroxide is collected in special filters and converted into magnesium chloride, using for this operation a 10 per cent. aqueous solution of hydrochloric acid which is largely derived from a later stage of the operation. The magnesium chloride is evaporated and dried until anhydrous, when it is electrolysed in suitable cells to produce metallic magnesium : hydrogen chloride is evolved from the cells. Natural gas is used as a source of power ; the effluent water is discharged 7 miles from the intake into a current of sea water which is always in the same direction.

Such, in a paragraph, is a description of a factory which is full of new methods and devices.

Magnesium, the lightest of metals, cost a sovereign a pound in 1915 and barely a shilling last year. It is expected that the capacity of a single sea water plant will be increased to 100,000 tons of metal by the end of this year, which represents an incredible number of gallons of sea water.

At the same factory, though in a separate plant, bromine is being extracted and the acid effluent from this mingles with the alkaline effluent from the magnesium to make a largely neutral return flow to the sea.

Magnesium metal was first made around 1869, mainly as a source of high intensity light for photographic purposes. Later on sundry uses in fireworks came along. It awaited war to start its use in aeroplanes and in incendiary bombs.

Magnesium in combination is one of the most abundant elements on the earth's crust. The most favoured source is magnesite, which in particular is used for refractories. Other sources are dolomite where it is associated with carbonate of lime and carnallite. If the metal is to be made by electrolysis, hitherto the favoured process, the magnesite has to be converted into chloride by briquetting the calcined material with carbon and binding substance and exposing to the action of chlorine in an electric furnace. Since in the course of electrolysis chlorine is evolved, the process becomes in theory cyclic, although in practice there is waste through formation of hydrogen chloride.

There are also competitive thermal methods for the reduction of magnesite to the metal. The two principal reducing agents are calcium carbide and ferro-silicon. The retorts are either externally heated by gas or internally by radiators. A good vacuum is maintained, and the metal distils in a pure form, only requiring melting. These processes can use dolomite in place of magnesite, merely at the expense of a smaller yield. There are many varieties of these processes, especially in America.

Direct reduction by carbon requires a very high temperature, for which an arc is necessary, and the vapour must be rapidly chilled in order to prevent the reversal of the reaction with CO, regenerating the oxide. In the original Radenthein process this was done by a jet of compressed hydrogen, cooled to a very low temperature. The magnesium was precipitated as a very fine dust, which had to be melted by high frequency current without exposure to air. Although much has been heard of this process it does not seem to have had much success. The Permanente Corporation in California uses natural gas as the cooling agent. The dust is collected, mixed with oil to a dough and distilled. The Ford Co. uses oil as the quenching agent, and a pilot plant of the Dow Co. is using molten lead, from which the magnesium can be distilled.

Magnesite made from sea water is proving a useful raw material for refractories. If calcined dolomite, a domestic British mineral, is used instead of lime to precipitate the magnesium from sea water a double purpose is served and additional magnesium hydroxide obtained.

It should perhaps be mentioned that the production of magnesium metal and of magnesite in the years before the war exceeded the demand : many new uses for the metal will require to be found to absorb the output when peace returns.

Certain minerals reach the sea either from sewage or by the leaching out of cultivated lands. Whilst these in the aggregate total far less than what is produced by denudation they are of importance because they represent those constituents which are of primary value to man. One of these is phosphate, of which the mineral deposits are limited in amount and likely to become exhausted. Many of the agricultural soils of the world are definitely short of phosphate and their crop-bearing qualities impaired in consequence. It has been calculated that the sewage from 5 million people is equivalent to 17,000 tons of rock phosphate in a year, and this quantity is equal to the amount of phosphate in the bones of the annual export of meat from New Zealand. The population of Great Britain discards as sewage yearly the equivalent of 150,000 tons of rock phosphate, most of which reaches the sea.

An estimate of the annual losses of phosphate from all sources to the sea in the United States amounts to the equivalent of 61 million tons of rock. The world's consumption of phosphate rock is said to be 18 million tons.

There is clear evidence that phosphate must be accumulating in the sea, unless it is somewhere being concentrated and deposited.

The chemist is already searching for materials capable of selectively absorbing and retaining substances present in small quantities in large volumes of water. Such base exchanging materials are widely used in the softening of hard waters and make it possible to take a good deal

of the salt out of sea water though not enough to make it drinkable by distressed mariners. What is wanted soon is a material which will extract the phosphates and concentrate them to an economic point ; the discovery of such agent should be feasible and may be imperative a generation or so hence.

The advantage of the sea as a source of minerals is that there is free access to it for any country which has a coast line. Its use, therefore, comes under the fourth clause of the Atlantic Charter. The knowledge of its constituents and its exploitation in the service of man depends upon the progress of scientific enquiry.

The costs of pumping are less than those of mining : on the other hand the ingredient desired, which may constitute 50 per cent. of a land mineral, may be present to the extent of much less than 1 in 1,000 parts of sea water. A technique of handling large volumes at low cost has to be elaborated before the sea can become a source of minerals.

It is of interest that some plants and animals have the power of concentrating certain of the ingredients of sea water. Iodine, for example, is present to the extent of 0·001 per cent., whereas the dry matter of deep water seaweed such as *Laminaria* contains 0·5 per cent. Kelp, or Varech, as it is called across the Channel, has been used for many years for the commercial extraction of iodine even though this practice cannot compete economically with the production of iodate from the *Caliche* in Chile. Certain coral species are said to contain up to 8 per cent. of iodine, and it is present here and in the bath sponge in the organic state as di-iodo-tyrosine.

To complete the story we should cite another natural organic halogen compound, Tyrian purple, the purple dye containing bromine derived from a mollusc, which was used to colour the togas of the Imperial Roman Emperors.

The seaweed moves lazily to and fro at our feet as the tide rises, we know what iodine signifies to us though we are without knowledge of what it means to the seaweed.

The oyster concentrates copper, which is another material which may some day be scarce and have to be obtained from the sea. It has been estimated in the United States that 200 tons of copper are lost in sewage per year per million people together with 50 tons each of such metals as manganese, lead, aluminium and titanium.

There is an interesting organism, the holothurian or sea slug, found off the Cornish coast, which has the power of concentrating vanadium in its structure though the quantity in the neighbouring rocks is so very minute.

A balance sheet between land and sea is instructive as showing the loss each year of considerable quantities of the rarer minerals. They must either be accumulating in the sea and be available for recovery or being deposited to form new areas of sedimentary rocks.

It is on record that for a whole month the very minute traces of gold in sea water were recovered at the great plant which extracts bromine. The gold was there, but at a cost several, stated to be four, times its value, so that the mines of South Africa need not feel anxious.

Probably many experiments are in hand to extract other coveted minerals from the sea. The chemist can do it, but at a cost which may not be competitive with a land source provided that this is accessible. The way to deal economically with large quantities has been shown. To solve such problems three things are essential, firstly skilled chemists and chemical engineers, products of the Universities ; secondly, immense quantities of cheap electric power ; and thirdly, a cheap source of heat. A country unable to provide any of these will fall behind in the race to produce even if it has ' free sea ' available.

Dr. Ernst Bergmann

The Dead Sea and its Surroundings

THE Dead Sea has attracted for many years the interest of geologists and chemists and has already played since 1930 a modest rôle in the supply of its three most important constituents, potassium salts, bromine, and to a very small extent, magnesium salts. With the outbreak of this war, its importance has suddenly grown considerably, as the main previous production centres of these three vital materials are now in Axis hands (potassium salts to an extent of 85·2 per cent. of the world production, magnesium to 66 per cent., and bromine to about 50 per cent.). The Dead Sea is now the only source of these commodities in concentrated form within the British Empire ; its possession has become of political and strategical importance—and it deserves, therefore, a brief description and a discussion of its future possibilities in the frame of a conference on Mineral Resources and the Atlantic Charter.

From the original reservoir of potassium salts, viz. the silicate layer of the solid earth surface, the potassium salts have been swept gradually by the rain into the rivers and from there into the sea. Together with the other solubilised salts, viz. sodium, magnesium, calcium, they have, therefore, accumulated wherever parts of the sea or inland lakes have evaporated. Such a process has occurred on a very large scale in Central Europe and has left its trail in the originally cohering salt deposits of France, Poland and Central Germany.

The process itself is still in constant operation at the Dead Sea in Palestine, where evaporation of water takes place over a surface of forty-seven miles length and nine miles average width, through absorption of solar energy of 630 calories per square centimetre and per day of twelve hours.

The water, by absorption of this heat energy, increases its temperature considerably above the air temperature ; a particular observation records a water temperature of 62° C., on a day with an air temperature of 37° C. ; thus, the evaporation becomes very efficient, about 250 per cent. more than on the already favourable shores of the Mediterranean.

The water and the salts are supplied by the Jordan and some other minor tributaries of the Dead Sea which bring with them 40,000 tons of potassium chloride per annum. While the ratio of the various salts remains constant, the absolute salt concentration increases with the depth, and from the available figures the following total

quantities of salts in the Dead Sea can be calculated.

Potassium chloride .	2×10^9 tons
Sodium chloride . .	$11{\cdot}9 \times 10^9$ tons
Calcium chloride .	6×10^9 tons
Magnesium chloride .	22×10^9 tons
Magnesium bromide .	$0{\cdot}98 \times 10^9$ tons
Magnesium . .	$5{\cdot}8 \times 10^9$ tons
Bromine . .	$0{\cdot}85 \times 10^9$ tons

How to explain geochemically the composition of this mixture is not quite clear, as the relative quantities of the salts differ from those in the Sea and in salt deposits. If one assumes that the salts originate from the influx of the Jordan, the calcium and sodium could have been supplied within 11,000 years, while for the magnesium and potassium 50,000–60,000 years would be required. A certain and perhaps variable part in the history of the Dead Sea is played by the hot springs of the Sea of Galilee, most of them discharging into the bottom of the lake ; it is probable that all the bromine is derived from these springs, which contain unusually high quantities of that element.

The two elements which so far have been mainly exploited are potassium, isolated in form of its chloride, and bromine.

In the course of manufacture, the water, drawn from a convenient depth, is subjected to fractionate evaporation in natural pans, which have an impervious clay bottom. First sodium chloride, common salt, crystallises, then a somewhat impure artificial carnallite, a double salt of potassium chloride and magnesium chloride, which in its natural form is also the starting material for the potassium chloride in the European mines, and finally magnesium chloride crystallises. The mother liquors go to the bromine producing plant. By an ingenious application of the solid-liquid equilibria of the salts concerned, highly purified potassium chloride is ultimately produced.

If one compares the quantities of potassium available from the Dead Sea with those available at the other centres of the potassium mining industry, one sees that the Dead Sea has still a great chance of further development. Suffice it to compare the 2×10^9 tons of potassium chloride in the Dead Sea with the total of 10×10^9 tons which the German industry possesses in form of carnallite. While according to the last published report (1938) of the Palestine Potash Co. 63,527 tons of potassium chloride have been manufactured, it can only be surmised that the production during the war has been considerably increased.

From the point of view of rational structure of the world industry, it must be considered unsatisfactory that none of the other technically important potassium compounds is manufactured in Palestine. This is only partly due to the fact that from an industrial aspect Palestine is still a very young country. The main reason for this unsatisfactory situation is the tendency of the heavy chemical industry in this country to concentrate the conversion processes in their hands and not to let a chemical industry grow up in Palestine, where it would be bound to become a powerful competitor, having the raw materials on the spot. But it is surely not rational, to take only one example, if Australia needs potassium chlorate to ship potassium chloride to this country, to convert it here into potassium chlorate, and to re-export it to Australia ; especially as the conversion into chlorate could be carried out without actual isolation from a concentrated potassium chloride solution so that one evaporation could be avoided and the total cost of production lowered.

Potassium salts are of vital importance for the war effort, not only because chemical industry is unthinkable without potassium hydroxide, not only because potassium chlorate has its uses in the explosives industry—if it is true that food is an ammunition of war, fertilisers are essential raw materials for such ammunition. And their value, and the extent to which they are used, will not decrease—as far as one can judge—when the war is over. It should be expected that agriculture will increase in volume after this war, even in countries previously considered as industrial—both because of the possibility offered by agriculture to employ and settle large numbers of people, and because of the fact that a New World will only be possible on the basis of a higher and more scientific standard of nutrition. If the United Nations prepare now a plan for the distribution of agricultural produce after the war they should also encourage, nay, enforce an increase in the productive capacity for fertilisers.

One of the most interesting constituents of the Dead Sea is the nearly 1,000 million tons of bromine, which is the largest quantity found at any single place in the world. Even Germany possesses only a total quantity of $0{\cdot}12 \times 10^9$ tons bromine, i.e. a seventh of the quantity accumulated in the Dead Sea. It is, therefore, not astonishing that the Palestine Potash Company is to-day one of the leading bromine producers of the world. Nature has in Palestine achieved a concentration of bromine which the chemical industry in America (and I believe also in this country) is trying to imitate.

Of course, the total quantity of bromine present in the Seven Seas is vastly superior to that available in the Dead Sea ; it is estimated to be 54×10^{12} tons. But the concentration, which is the determining factor in the industrial exploitation of this wealth, is with 54 g. bromine per cbm. only about 1 per cent. of that present in the Dead Sea, which is 4,800 g. per cbm. And the end liquors of the potassium chloride and magnesium chloride production, which are actually used in Palestine for the production of bromine, have a concentration as high as 14,000 g. bromine per cbm.

It appears that the Middle East shows a certain affinity to bromine. It may be recalled that the antique purple manufactured in Sidon and Tyre is a bromine-containing dye-stuff, the purple snails having apparently been one of the several known strange instances of selective affinity of cells to a specific element. One may well consider it strange as the antique purple is the only organic bromine compound which has been found so far in any living cell. Perhaps the existence of such specific affinity may account for the relatively large quantities of bromine in the Dead Sea ; if bromine containing maritime organisms have decayed in the soil, the bromine would be swept away by hot springs in form of inorganic bromides.

One can assume—statistical figures not being

available—that practically all the bromine produced in the world is consumed in war industries. Probably the largest part of the bromine is required for ethylene dibromide, the second major constituent of tetra-ethyl lead fluid ; but also other organic bromine compounds have become important, such as methyl bromide, because of its use in fire extinguishers. In general, the industrial chemistry of bromine has not yet been fully explored. It is certain that with the easier availability of the element a number of promising possibilities will materialise apart from the use in various pharmaceuticals, which obviously require only minor quantities.

The third constituent of the Dead Sea which deserves closer attention is the magnesium which we have seen to occur in the Dead Sea to an extent of 5,800,000,000 tons. I need not recall the importance of magnesium in the light-metal industry, i.e. in the construction of aeroplanes, and I believe it is not exaggerating to say that it is unsound to work up sea water with the magnesium content of 0·5 per cent. for magnesium metal, as is done to-day, and not to make use at all of the eight or nine times higher concentration which Nature affords in the Dead Sea. It is true that in the production of magnesium metal the price of electricity plays a decisive rôle and that electricity in Palestine is a much too expensive commodity. But surely it is more rational to adapt the production of electric power to the concentration of magnesium than to adapt the concentration of magnesium in sea water to the price of electricity.

There can be no doubt that if the quantities of magnesium industrially available increase, and incidentally the cost price decreases, many other uses will be found. One of the objections raised against the use of magnesium metal has e.g. been that it is strongly corroded by sea water. In recent years, however, methods have been developed to give the magnesium surfaces a coating, e.g. with an alloy of magnesium and certain rare elements which is said to afford satisfactory protection against such corrosion. Alloys of magnesium with such rare elements, e.g. with 1–2 per cent. silver, have also other mechanical advantages, e.g. a higher proof stress.

All these considerations taken together tend to show that the Dead Sea may become a source of industrial life perhaps unequalled by any other natural concentration of mineral wealth. This antithesis is perhaps not as strange as it appears at first. The Dead Sea does not quite deserve its name. Recent investigations have shown that the assumption its water is bare of any life was too obvious to be true. A fair number of bacteria and other micro-organisms such as flagellatae and algae have been observed in the Dead Sea and as a matter of fact it is one of the most puzzling problems in biology how cells can exist surrounded by such a concentrated salt solution, without losing their water under the influence of the osmotic pressure to the outside, without shrinkage and sudden death. Would it be possible that the laws of osmotic pressure are no more applicable to the extreme salt concentration which we find in the Dead Sea and other similar salt lakes? Nature has certainly unexpected means of protecting the life of organisms and the way in which they create their energy requirements.

Nature has also provided some elementary form of energy which could be utilised for the exploitation of the Dead Sea. In general, for geochemical reasons potassium deposits are connected with oil deposits—quite naturally so, as oil originates from the decomposition of a maritime flora and fauna. Whether oil is to be found in the immediate vicinity of the Dead Sea is not yet known, but it has been known for a long time that the mountains separating Judaea from the Dead Sea consist to a large extent of a bituminous limestone. In the prospected area, approximately 24,000,000 tons of this stone are available, containing up to 20 per cent. organic matter and giving on destructive distillation up to 11 per cent. of its weight in form of a shale-oil which could be used to generate the power and to form the fuel required for the prospective development of the Dead Sea.

Together with this oil, which has a thermal value of 18,000 B.Th.U. per pound, a gas is formed in a quantity of 27 cbm. per ton and with a calorific value of 800 B.Th.U. per cu. ft. One ton of limestone would, therefore, give about 23 therms.

From the point of view of inorganic heavy industry, it is not uninteresting that the shale-oil contains about 10 per cent. of sulphur in form of organic compounds which can easily be desulphurised. The sulphur thus liberated can become the source of the sulphuric acid which will be required in the production of one important potassium fertiliser, viz. the sulphate from the potassium chloride of the Dead Sea.

In this respect it may be mentioned that in the Gaza area in the south of Palestine a large sulphur deposit has been discovered, representing according to an approximate evaluation at least 1,000,000 tons of sulphur, so that all the sulphuric acid required in the production of potassium sulphate could be made from local raw material.

And then another industrial possibility offers itself. If potassium sulphate were manufactured, large quantities of hydrochloric acid would become available, which in general is considered an undesirable and noxious waste product of chemical industry. But there is one process in which hydrochloric acid is advantageously used, viz. the conversion of phosphate rocks into fertiliser phosphates. Phosphate rocks, tertiary calcium phosphate, are so insoluble that they cannot be absorbed by the capillaries of plant roots. The secondary calcium phosphate, however, is soluble enough, and the conversion can be carried out by means of hydrochloric acid. The Transjordanian shore of the Dead Sea has considerable phosphate deposits and also on the Palestinian side large deposits have been studied representing a somewhat less concentrated tricalcium phosphate, viz. of 43–56 per cent.

While the suggestion to transport these phosphates to the Mediterranean ports and from there to phosphate fertiliser manufacturing countries was economically unsound, it may prove interesting to carry out the conversion on the spot and so to supply the markets in the Middle and in the Far East with two of the three essential fertilising elements, phosphorus and potassium.

I must admit that this survey presents only partly facts and to a large extent possibilities. But in the frame of this Conference it is as well to

define where we stand and to indicate which lines could be followed if every country is allowed to develop its resources in the most rational way—rational from the point of view of a co-ordinated world economy. If thus this Conference must devote itself both to a survey of the past and to an outline of the future, this is doubly appropriate in the case of Palestine, which has always and more than ever in the last two decades drawn its energy from the past and from the hope for a prosperous future, never depressed by the troubles of a dangerous present. If in future the Jewish Palestine is given the possibilities which the Atlantic Charter has promised the oppressed nations, the Dead Sea can and will become one of the supply centres of the world.

Dr. W. H. Hatfield, F.R.S.

Economy in the use of Ferro-Alloys

In times of peace, particularly if they are of long duration, the qualities and characteristics of that which is produced are the result of tradition and usage, salesmanship, and the developments due to technical progress based on the application of old or new knowledge. Tradition, usage, and salesmanship slow up in measure the inevitable progress towards the realistic efficiency possible through knowledge and the consolidation of technical progress. War and preparation for war insists upon stark efficient realism, and those who prepare for war are given more time to attain to it than those who are unexpectedly called upon to face such conditions. Also, in times of peace, international trade throws open to all countries the world's resources in raw materials and facilities on an economic basis ; war rudely disturbs this state of things and realism in production must then deal with a limited or changed availability of that upon which production can continue.

These conditions apply at the moment to the production of steel, and particularly to special and alloy steels. Concerted efforts are being made within the industry to attain maximum efficiency based on the availability and changing availability of raw materials and facilities. It will be obvious that technology and technique so developed can be, and will be, projected with advantage into post-war times.

It is perhaps of value to consider the twenty-five elements which are of direct interest in the production of steel. In the attached table those elements will be found scheduled. They can be divided substantially into four groups, i.e. (i) the dominant alloying elements, (ii) the secondary alloying elements, (iii) appertaining and arising essentially as regards process, (iv) for protective coating.

Of these twenty-five elements, knowledge of seven—copper, zinc, carbon, tin, lead, sulphur, and last but most important of all, iron—was bequeathed to us by early civilisations and a period of some two thousand years passed before we seriously began isolating those which are now so useful.

Of the dominant alloying elements, i.e. manganese, chromium, nickel, molybdenum, tungsten, cobalt and vanadium, it is of great interest to note that four of these elements were originally isolated in Scandinavia, one in France, one in Germany and one in Spain, whilst of the secondary alloying elements, aluminium, titanium, zirconium, niobium, selenium and copper, three were isolated in Scandinavia, one in France, and one in Britain, whilst the last mentioned, copper, was employed in prehistoric times.

As regards the elements iron, carbon, and silicon, these are so fundamental as almost to escape notice, but whilst iron and carbon date from prehistoric times, silicon was only isolated in 1854 in France. Hydrogen, nitrogen, phosphorus, arsenic, oxygen, sulphur are to be looked upon as essentially impurities arising from the process, whilst zinc and tin are used for coating steel in protection against rust (as of course in smaller degree are cadmium and nickel).

In an effort to be able to present a complete picture the author sought to :

(*a*) Schedule the production of the relevant raw materials as regards country of origin.
(*b*) Schedule the countries where the raw materials were smelted or reduced to a usable form.
(*c*) Schedule the origin of the relevant raw materials used by the different steelmaking countries.

Such statistical evidence merits careful study and although not sufficiently available for a complete statement, does point to facts of great interest to this meeting.

The volume of production of an ore in a country is indicative of the achievement of economical winning, but not necessarily of the resources prevailing. There may be great quantities of low grade ore, railways may not be available, and population of a suitable character may not be there. Distance too is determining from the economic point of view ; for instance, a great country may find it advantageous to obtain material from a neighbouring country rather than from within the confines of its own extended territory. The geologist locates, the mining engineer advises on practicability, and the industrialist backed by adequate finance seeks to develop these relevant deposits. Sound knowledge, enterprise and no little courage is demanded. The collective outcome normally is availability in reasonable relationship to world demand.

Without exception, the steelmaking countries do not possess complete essential resources and must import much that is necessary. In normal times, international trade provides the necessary facilities at world prices on a reasonably economic basis. Small countries as well as large ones have successfully developed important steel industries.

To implement the foregoing it is interesting to examine a few cases and then it will be obvious, having in mind present world conditions, that it is essential to use available alloys on their intrinsic technical merits and only to the absolutely essential degree.

As regards the principal alloying elements used in the alloy steel industry, manganese ore, whilst widely distributed, is produced essentially in Russia, India, West and South Africa, Brazil and Germany. Nickel ore production is focused essentially on localised deposits in Canada. Chrome ore, whilst very widely distributed, is

produced in Rhodesia and South Africa, Turkey and U.S.S.R., and in lesser degree in Cuba, the Philippines, India, Yugoslavia and Greece. Tungsten ore is essentially produced in China, Burma, and in less degree in the U.S.A. and South America. Molybdenum ore production is focused essentially on deposits in the United States of America. Vanadium ore is produced essentially in Rhodesia and South West Africa, U.S.A. and Peru. Cobalt ore is derived principally from the Belgian Congo, Rhodesia, French Morocco, Canada and Burma.

It will thus be seen that the principal steel producing countries — U.S.A., U.S.S.R., Germany, Great Britain, France, Japan, Belgium, Luxembourg and Scandinavia—are dependent upon the normal functioning of international trade and copious transport, particularly in the form of shipping.

Great Britain relies upon importing 30 per cent. of her iron ore and the whole of her manganese, chrome, nickel, tungsten, molybdenum, vanadium and cobalt. Germany relies upon importing most of her manganese ore and the whole of her chrome, nickel, tungsten and molybdenum ; she claims to recover her vanadium at home. The U.S.A. imports over 90 per cent. of her manganese ore and practically the whole of chromium, nickel, cobalt and a substantial proportion of her requirements in tungsten. It is thus obvious that the conditions postulated in the fourth clause of the Atlantic Charter did operate even in the period between the two great wars, or how can one explain for instance the successful iron and steel industries of Scandinavia and Belgium—Luxembourg ?

One of the greatest technical achievements is the colossal output of iron, and by virtue of the influence which carbon and other elements can confer readily upon it, a very wide range of properties are available. Steel may be soft and ductile, hard and of great strength, wear resisting, rust and acid resisting, heat resisting ; may be of high permeability, capable of a high degree of permanent magnetism, may be non-magnetic, have a high electrical resistance, or a low coefficient of expansion. It may possess various combinations of these and other properties as required. It can be converted by added elements into any of a wide range of tool steels and steels for many special applications. These results are attained by a knowledgable heat treatment superposed upon a selected suitable composition.

Some fifteen elements are involved in the production of these various properties, and it will at once be apparent that millions of alloys of various compositions would need to be tested out really to put this phase of metallurgy upon a finally quantitative basis. Thus some properties may be achieved by using different proportions of different elements and that fact coupled with other factors operating in the world, has resulted in quite a complexity as regards the number of steels available. The obvious thing is for the producer and user in co-operation only to use those compositions which are most effective and most in sympathy with the availability of the materials.

The problems before such a collaboration are influenced by many variables. There is the peculiar combination of properties required for a particular purpose, achieved by complex compositions which although they in practice achieve their purpose, have been found to do so by practical trial ; that is, by ' trial and error ' method ; and it is not always easy in a steel containing a number of alloyed elements in different proportions to diagnose the extent to which amounts of each individual element contributes or to what extent the selected superposed heat treatment is responsible for the ultimate result. Again, it can be argued that so long as the necessary mechanical and physical properties are secured, the composition and treatment are of secondary importance ; this might truly be argued, were it possible by testing methods alone to ascertain definitely whether the conditions for a particular service have been achieved. Laboratory tests to simulate the calls of service are valuable, but they are generally incomplete. Even the designer, try as he may, is never sure of being able to postulate completely on paper the conditions which he has to meet and then provide the means of meeting them.

Thus, by practical experimental procedure based on existing knowledge, mechanisms and apparatus are provided, built of materials which by trial are found to serve the purpose. It is, therefore, not a matter of surprise that when success has been painfully achieved by modifications here and there as dictated by circumstance, the means whereby success has been achieved are fairly rigidly adhered to. When stock is taken in a national emergency, multiplicity of types of material and of design is to be expected. The next step is to facilitate mass production by strictly limiting the number of designs and vastly reducing the number of types of material.

What has been done as regards the metallurgy of steel, particularly as regards special and alloy steels ? In May, 1940, the Special and Alloy Steels Committee constituted its Technical Advisory Committee with a mandate to deal with this problem. It was found that the production of the steels was governed by between two and three thousand specifications. The first step was, therefore, a meticulous study which resulted in the sorting out of the whole of the steels covered by the specifications, into eighty-five categories essentially upon the basis of mechanical properties, compositions or special functions. The T.A.C. Schedule 1–85 did not lend itself to general publication since it was all embracive, but it permitted the appropriate authorities and individuals to survey the interesting position thus disclosed.

The main point achieved was that it became possible to measure up needs against availability as regards the essential alloying elements. Means were found by the Steel Control assisted by the goodwill of the industry and the consumers to accommodate manufacture with quite reasonable success to changing conditions. Still conditions change, but in the truly indigenous British manner of adaptation to changing circumstance, the means of adaptation now exists which it may be presumed will achieve as much as is possible according to the existing conditions and needs of the moment.

The T.A.C. Schedule of eighty-five categories

for so many specifications was possible owing largely to the manner in which the same object was being achieved by different or slightly different compositions and treatments. Thus, as will be described, selection was possible of a relatively few appropriate compositions and treatments to facilitate mass production, but at the same time alternative steels became scheduled and so material guidance exists for change with availability as the need arises. How far can results be achieved without alloy additions ; how far can we replace nickel with chromium or chromium with nickel ; how and in what circumstances are molybdenum and vanadium essential ; can we replace tungsten with molybdenum or molybdenum with tungsten ; will a modified heat treatment with a different composition give the same characteristics ? A survey of the categories of the schedule assists in answering some of these questions.

In 1941 advantage was taken of the existence of the British Standards Institution to issue document BS970/1941, giving in the form of fifty-eight specifications the principal and most useful of the steels in the Schedule covering wrought carbon and alloy steels for general engineering purposes in dimensions up to 6-in. ruling section. This document was shortly followed by BS971, which implemented the contents of BS970/1941 with much technical and other useful data facilitating the successful application of the selected steels ; this document sets a precedent in form. At this stage the Steel Controller issued a direction through the British Standards Institution BS970A, indicating that in conformity with existing conditions, certain steels specified in BS970/1941 should in the absence of special sanctions be the steels applied in future programmes. Thus the ' En Series ' of war steels entered their useful career. On March 30, 1942, a brochure was issued indexing and correlating the great mass of specifications to the steels of the Direction 970A which sought to replace them. Two remaining steps should be mentioned ; BS970/1941 was revised and is re-issued as BS970/1942, and representatives of all the services, after deliberation upon the steps already taken, issued through the British Standards Institution Document BS/STA5, which co-ordinates the whole of the requirements of the services within the terms of reference with the composition and properties of the steels of the direction on the basis of the En Series contained in BS970/1942.

This successful collective effort at unification has only been possible as a result of the firm determination of all parties to attain that which was intended. Finality under present changing circumstances is not possible, but succeeding documents under the ægis of the same authorities will, it is hoped, successfully keep up to date such essential data.

The fortunate Crusader had a superbly efficient Toledo sword of high temper ; that is, the blade had a tensile strength of over a hundred tons per square inch. This was obtained by the diffusion of carbon into wrought iron and the steel so produced when heated above the critical point became a solid solution of carbide or carbon in iron ; rapidly quenched in water from this temperature the blade was intensely hard and also brittle, but when lightly tempered by reheating to a skilfully selected temperature, material hardness was still retained but was accompanied by a remarkable toughness. Such results can only be obtained in such thin sections ; if heavy pieces of such steel are quenched from the hardening temperature, the actual rate of cooling becomes so relatively slow as to allow the solid solution to break down and hardening is not achieved. Nevertheless, modern carbon steels which, unlike the steel of medieval times, contain a substantial quantity of manganese, may be hardened and tempered in the form of bars of quite useful sizes with resultant considerable strength and ductility. The exploitation of such material to the greatest practical extent is most desirable at the present time.

The use of a particular composition of steel necessary for a particular application is governed by the strength and properties required and by the sectional area, or to be more correct, the ' Ruling Section.' If the mass is considerable and the strength required great, a rich alloy steel is essential to ensure success in hardening, and therefore the possibility of superposing upon the quenched condition by tempering a desirable toughness associated with the degree of strength required. This short paper does not permit a detailed discussion of this particular field, but the relevant information will be found in the documents to which reference has been made.

In heavy masses where it is desired to obtain properties resulting from hardening and tempering, as much as 5 to 6 per cent. of alloying elements is necessary, i.e. chromium and nickel, and these elements may be used in different proportions with a material degree of interchangeability, according to availability. Under such conditions a small proportion of molybdenum is desirable essentially to preserve higher values in resistance when required to the notched bar impact test and in part to reinforce the hardening properties. As the mass or section decreases, less alloy is needed and this aspect is given quantitative guidance on alternate bases in BS970/1942 and BS971. Thus the heavy use of alloying elements should be restricted according to mass.

The remarks so far refer to the development of strength and hardness in different degree by the processes of hardening and tempering. There are a considerable number of instances where alloys used in greater quantity produce important and entirely different characteristics : 13 to 30 per cent. of chromium and 2 to 20 per cent. of nickel, together with lesser amounts of other elements, are necessary to produce rust, acid or heat-resisting steels. Large quantities of tungsten and/or molybdenum, together with material quantities of chromium, vanadium and cobalt, are used to produce high speed cutting steels. High percentages of manganese are necessary to produce the wear-resisting properties of the austenitic manganese steel. Many other special purpose applications could be quoted. The use of such steels owing to their high alloy content is being carefully watched and controlled.

The problem is a considerable one ; namely, how at the present time to cater for a greatly increasing demand for steels of the necessary properties with a changing availability and a

considerable deficiency in some of the essential elements. Never has a more interesting technical situation developed, for solution by scientific and technical minds.

Autocracy in science or technology is as deadly as in the political field. In these efforts within the steel industry, our work is being advanced by the friendly and enthusiastic collaboration of many minds; the co-ordination of different points of view has resulted in, and is operating, a workable procedure.

Stark efficient realism is necessarily our theme.

TABLE OF THE ELEMENTS OF INTEREST IN STEEL METALLURGY

Element.	Group.	Date. Isolated.	Metal Isolated by	
Hydrogen	I.	1766	Cavendish	British
Copper	I.	Prehistoric	—	—
Zinc	II.	Prehistoric	—	—
Aluminium	III.	1854	H. St. C. Deville	French
Carbon	IV.	Prehistoric	—	—
Silicon	IV.	1854	H. St. C. Deville	French
Titanium	IV.	1825	Berzelius	Swedish
Zirconium	IV.	1824	Berzelius	Swedish
Tin	IV.	Prehistoric	—	—
Lead	IV.	Prehistoric	—	—
Nitrogen	V.	1772	D. Rutherford	British
Phosphorus	V.	1669	H. Brand	German
Vanadium	V.	1830	Sefstrom	Swedish
Arsenic	V.	1240	Albertus Magnus, Bishop of Regensburg	German
Niobium	V.	1801	Hatchett	British
Oxygen	VI.	1774	Priestly	British
Sulphur	VI.	Prehistoric	—	—
Chromium	VI.	1798	Vauquelin	French
Selenium	VI.	1818	Berzelius	Swedish
Molybdenum	VI.	1782	P. J. Hjelm	Swedish
Tungsten	VI.	1783	F. D. and H. J. D'Elhuyar	Spanish
Manganese	VII.	1774	J. G. Gahn	German
Iron	VIII.	Prehistoric	—	—
Cobalt	VIII.	1742	Georg Brandt	Swedish
Nickel	VIII.	1751	Cronstedt	Swedish

Sir Harold Hartley, C.B.E., M.C., F.R.S.

The Recovery of Metals from Scrap

THE dominant feature of industrial development in the nineteenth century was the use of power, but closely associated with it, and of hardly less importance, was the enormous increase in the use of metals made possible by metallurgical progress. In 1800, for instance, the world production of iron and steel was about half a million tons; in 1900 it was forty million tons and now is over three times as great. This rapid growth in the use of metals made serious inroads into the world reserves of ores, and in some countries the available resources, particularly of the richest ores, were exhausted or seriously depleted. Conservation has therefore become an urgent problem, and closely linked with this is the question of the ultimate fate of metals in service and their recovery as scrap. To what extent are they lost in use? To what extent do they follow man-made cycles like the well-known carbon cycle in nature, so that the world stock is not depleted?

There must be losses in the use of metals or alloys due to wear, corrosion, heat and dispersal which dissipate them so that they cannot be recovered; similarly their use in chemical compounds such as pigments tends as a rule to total loss. The only examples of metals in which there is little such wastage apart from their use in plating or in thin films are the so-called precious metals, gold, silver, and the platinum group. An exact study of the fate of the industrial metals is impossible owing to the lack of accurate statistics, and to the uncertainty as to their secondary uses, but it is clear that in this century scrap is playing an increasingly large part in metal production and must enter into any comprehensive survey of world metal supplies in the future.

In the United States, for example, it is estimated that in recent years (1929–1938) ferrous scrap has amounted to 75 per cent. of the output of steel, while non-ferrous scrap has accounted for 50, 45 and 35 per cent. of the total domestic consumption in all forms of copper, lead and aluminium respectively. Any prejudice against the re-use of scrap has disappeared with the evidence that with due precautions the secondary metal recovered by the secondary metal refineries is the equal of the primary production from the ore.

Each metal presents a different problem according to its nature and uses, but there are certain general aspects to be considered first in order to clarify as far as possible a somewhat confused and puzzling picture.

The Definition of Scrap.—The word 'scrap' is used in this paper in the sense usually understood to cover what are often described as secondary, reclaimed or runaround metals. Obviously there are different types of scrap which may be defined to indicate their origin as :—

1. *Process Scrap.*—Scrap arising in the production of a finished or semi-finished article before it reaches the machine shop, which is re-used in the plants of origin. This includes ingot heads, gates and risers from castings, crop ends of rolled material, trimmings from sheets, tubes, etc., all of which are normally returned to the melting furnaces in the same works.

2. *Engineering Scrap.*—Scrap such as swarf, drillings, turnings and rejects produced in engineering shops which are usually separated from the primary production, so that this scrap cannot be so quickly absorbed. Further, its physical character and high degree of oxidation often make it difficult to use in re-melting furnaces. This has brought into existence a new branch of the non-ferrous industry, the secondary metal refiners, whose function is the recovery of metal from engineering and old scrap.

3. *Old Scrap.*—This consists of disused material arising from obsolescence, accident and wear. Recovery of this is a skilled trade involving the breaking up of machinery into its component scrap categories, e.g. a motor car may contain no less than twenty-five different ferrous alloys and the same number of non-ferrous alloys.

It is, of course, impossible to make hard and fast distinctions between these three classes, particularly between 1 and 2, but these two classes cover new scrap, metal that has not been in service, as distinct from old scrap. Scrap of classes 2 and 3 may, however, easily get mixed in the process of collection before reaching the producer again.

Disposal of Scrap.—The disposal of scrap metals and their use to the best advantage is becoming more complicated each year owing to the increasing use of alloys. The whole problem would be vastly simpler if metals were used mainly in a pure state or admixed in the case of iron with carbon alone. In many cases, e.g. bearing metals and tool steels, the alloys are kept separately in the process of collection for re-use after re-melting and adjustment of their composition, as the recovery of the constituent metals from their alloys would be a wasteful and often a difficult and uneconomical operation. The sorting and classification of scrap is therefore a matter of great importance. For process scrap it is an easy matter as this goes straight back to its own melting furnace. For engineering scrap the segregation is relatively easy if it is properly organised in each works, but the scientific sorting of old scrap presents much greater difficulties and requires careful organisation to avoid waste. The higher prices paid for special alloys are an incentive to make the sorting as effective as possible. However, this is not so easy with small admixtures of alloy metals and increasing difficulties are arising from the presence of these in undesirable quantities in the recovered metal.

One of the main difficulties of getting a true statistical picture of scrap recovery is the extent to which certain scrap is re-used directly without coming into the market. This applies to all process scrap and to a certain amount of engineering scrap which is recovered directly, e.g. brass turnings go direct back to the brass foundry. In large organisations there is also a considerable internal re-use of old scrap which would not appear in any statistics. For instance, railway chairs go back to the foundry which may use as much as 95 per cent. of old scrap. Bearing metals are also recovered internally and re-melted with the necessary additions of virgin metals, which alone appear in the statistics. Similarly, copper scrap must reach the brass foundry unaccounted for, as the amount of copper used in brass making is less than the equivalent amount of zinc which is known to be used for this purpose.

The picture is complicated further by the re-use of suitable old scrap for the direct manufacture of other articles. For example, the re-rolling of old rails to produce a variety of articles is carried out on a considerable but unrecorded scale, and locomotive axles can be forged down and heat treated to make crank pins of smaller diameter, or used for many other purposes. Small bars of mild steel can be used for drop forgings. The re-fabrication of old scrap has been greatly helped in recent years by welding, and especially during the war has made considerable progress. Much of this re-use of scrap which makes a considerable contribution to the conservation of mineral resources does not appear in any statistical review.

Relationship between Total Production and Scrap Recovery.—The volume of consumption of metals at any moment depends on new demands and on replacements due to obsolescence, corrosion and wear and tear. It is therefore clear that unless there should be heavy accumulations of scrap or new demands had vanished in a severe depression, the amount of scrap arising from replacements must always be less than the total amounts of metal required for current production. The relation between the two will vary with the metal and the circumstances. What are the main factors that influence the volume and rate of return of scrap ?

With the modern tendency to rapid development and quicker obsolescence, the life cycle of metals will in general be shortened. On the other hand, welding has made possible the repair of steel, e.g. at rail ends and in locomotive fire boxes, which will increase the service life of metals. The development of improved materials with increased hardness, greater resistance to wear and fatigue, and to corrosion (including painting and surface treatment) also tends to lengthen the life cycle and eliminate losses of metal. The use of lighter designs, the increasing use of sheet metal and of a multiplicity of small gadgets may, however, tend to make scrap recovery less complete.

An interesting point arises in connection with the increased use of reinforced concrete in place of steel construction. This effects a considerable saving of steel amounting to 50 or 60 per cent., but on the other hand it is not economical to recover much of the steel in reinforced concrete, while the bulk of a steel frame can be salvaged.

For iron and steel, corrosion is the biggest factor, which Speller estimates may lead to an annual replacement of 2 per cent. of the total

tonnage in use. For other metals the effect is much less, as is shown in the following table giving the results of exposure of metals in the industrial atmospheres of Birmingham and Sheffield. The two sets of results are expressed differently, but the metals appear roughly in the same order in each.

Relative Atmospheric Corrodibility of Metals

Metal	Friend, *J. Inst. Metals*, 1929, 42. (Seven years in Birmingham City air.) Loss of weight per cent.	Hudson, 'Corrosion of Iron and Steel,' 1940. (Sheffield industrial atmosphere.) Rate of corrosion (mils/year).
Mild steel	10·3	5·0
Wrought iron	6·7	3·8
Cast iron	3·5 (approx.)	Good resistance
Zinc	0·54	0·70
Nickel	0·47	0·41
70/30 Brass (2 Pb)	0·39	0·57
Copper	0·18	0·28
Aluminium	0·11	—
Tin	0·10	—
Lead (soft)	0·09	0·26
Stainless steel (12 Cr)	0·10	—
18 Cr, 8 Ni	—	0·003

When all these variable factors are taken into account, and also the uncertain statistics as to the use of scrap, it is not surprising that it is impossible to draw up an exact balance sheet covering losses and recovery of any metal, as will be seen in the sections dealing with the separate metals.

Iron and Steel.—At present iron and steel represent about 93 per cent. of the total world tonnage of metal production. This figure, however, would give quite a wrong impression of the relative importance of ferrous and non-ferrous scrap recovery, as in U.S.A. the actual value of the small proportion of non-ferrous production is roughly equal to that of the much greater amount of pig iron. It has been estimated that of the total output of iron and steel, 15 to 20 per cent. is lost from rusting, and that in all 35 per cent. is lost irrecoverably due to rust, dispersal, and the use of iron and steel in articles from which recovery is uneconomic. Sixty-five per cent. is thus left to find its way back into use, of which 25 per cent. is process scrap which does not leave the steel works, and the remaining 40 per cent. returns at a rate dependent on obsolescence, wear and the state of industrial activity. With improved protection against rusting, losses will be reduced, but quicker obsolescence will shorten the life cycle.

The following figures (in millions of tons) for recent steel production in this country confirm this estimate, remembering that some scrap goes to blast furnaces and that an addition must be made to the percentage of scrap in the table to allow for this :—

Year	*Total Production*	*Pig used*	*Scrap used*	*Per cent. scrap*
1935	9·6	4·6	5·8	56
1936	11·8	5·6	6·9	55
1937	12·9	6·2	7·5	55

The recovery of ferrous scrap in the United States has reached a higher figure in recent years, averaging 75 per cent. of the steel production, possibly due to quicker obsolescence.

Diagram I shows the tonnage of steel production and scrap recovery in the United States from 1900 to 1938.

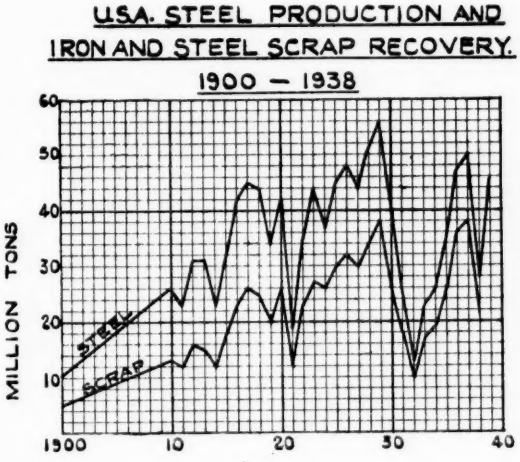


DIAGRAM I.

Diagram II, on the following page, illustrates the life cycle of iron.

The main difficulty which has arisen in the recovery of ferrous scrap is due to the increase in the number of alloys, which makes it increasingly difficult to segregate scrap of similar character. The result is that the amount of the residual elements tends to increase in ordinary steel, producing undesirable results. For example, the presence of nickel and chromium may produce a steel very different in characteristics from the steel required. Rejection has occurred from this cause, emphasising the importance of improved methods for segregating most carefully scrap from alloy steels of various compositions, in order to utilise them most economically and to avoid the presence of elements which may upset the normal properties of the steel. The introduction of controlled grain-size straight carbon steels often avoids the need for using alloy steels, and they have the additional advantage of simplifying the recovery of scrap, since they contain no other elements.

In the case of alloys with a high percentage of other elements, e.g. stainless steel, or tool steels, the large differential in scrap price is an incentive to see that they are kept separate.

Manganese.—There is only a small recovery of manganese in the form of high manganese alloys, as the bulk of it is used in steel manufacture as a deoxidiser and desulphuriser and is lost in the slag.

Nickel.—Only a small percentage of nickel is recovered, as much of it is lost in low nickel steel alloys which go into ordinary scrap or in nickel plating. Undoubtedly more could be saved by the segregation of nickel alloys. Recovery is presumably better for the high nickel alloys. In the United States scrap recovery has progressed steadily, and in 1938 was about 2,000 tons, which is, however, only a small percentage of consumption.

Chromium.—Little is known about the recovery of this metal, except that its high price encourages recovery by producers and fabricators of the alloys and by large consumers. The expanding demands for chromium steels will make the segregation of chromium alloy scrap of increasing importance.

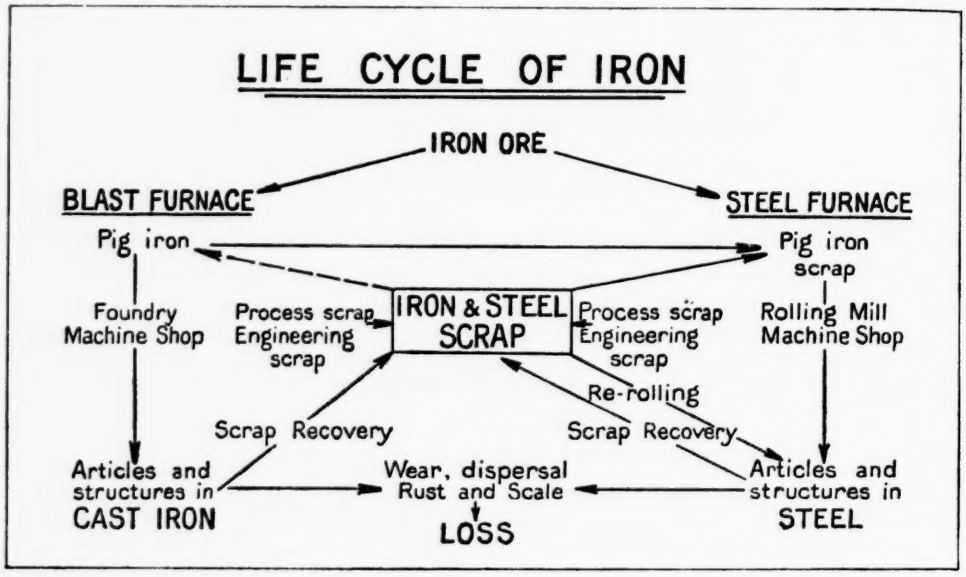


DIAGRAM II.

Copper.—The United States statistics for copper recovery are more complete than for any other metal, and so it is possible to give a clear picture of the position. Owing to its relative freedom from corrosion wastage should be relatively small and the value of the scrap is favourable for salvage.

Copper is recovered and passes into use again both as metal and as brass and other alloys, and it is important to distinguish between the two. United States statistics for 1929–1938 show that of the domestic consumption of copper metal, approximately 6½ million tons in those years, 2⅓ million tons or 39 per cent. came from scrap recovery. Of this roughly one-third came from new scrap (process and engineering) and two-thirds from old scrap. Scrap recovery in addition yielded nearly two million tons of copper in the form of brass or alloys which were re-used. The total contribution of recovery, therefore, to the domestic use of copper in all forms was approximately 50 per cent. for this period.

Diagram III shows how the consumption of copper in all forms in the United States in these years was provided under three categories :—(1) The primary production of copper from its ores, (2) the secondary production of copper metal from recovered scrap (new and old), (3) the re-use of copper in alloys recovered as such from scrap.

The trend of scrap recovery over a period of years shows a close relation to the index of industrial production. Increasing prosperity means new consumption and the quicker replacement of obsolescent articles. Increased production means increased new scrap and the flow of old scrap depends on the rate of replacement. Apart from stocks this flow is in fact a direct function of current consumption. Hence it is not surprising that the volume of scrap recovery of copper should be related more closely to the index of production than to current scrap prices. The length of the life cycle of copper is not fixed, but will vary with the level of industrial activity, and other factors such as the production of quickly obsolescent designs.

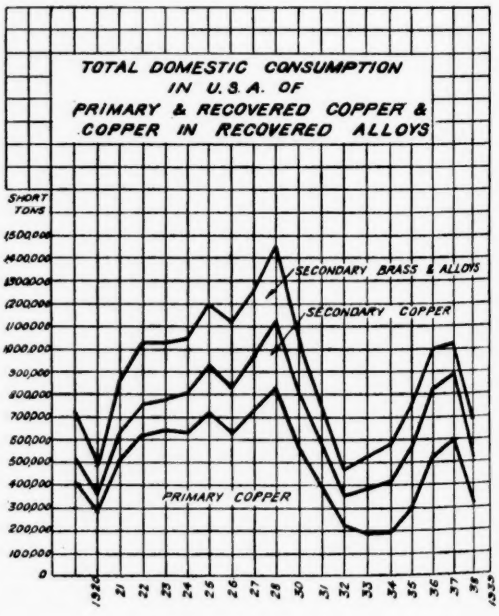

TOTAL DOMESTIC CONSUMPTION IN U.S.A. OF PRIMARY & RECOVERED COPPER & COPPER IN RECOVERED ALLOYS
SHORT TONS
SECONDARY BRASS & ALLOYS
SECONDARY COPPER
PRIMARY COPPER

DIAGRAM III.

Tin.—About half the total tin production is used as pure metal for making tinplate and as foil for various purposes. The rest is used in

various alloys, solder, bearing metal and bronzes. Tin is recovered from the clean tin scrap and from the dross arising in the course of manufacture of tinplate, but the recovery of tin from used cans is not in general economical owing to the difficulty of collecting and cleaning them. There is also a considerable recovery from tin alloys. United States statistics for 1929–1938 show a recovery of metallic tin from scrap amounting to 8 per cent. of the total consumption as pure tin and alloy, and a recovery in the alloy form amounting to 26 per cent., so that on an average one-third of the consumption in all forms was provided from the recovery of scrap. About 6 per cent. of the tin is used in various chemical compounds, and this is irrecoverable.

Lead.—The major uses for lead are storage batteries, cable covering, sheet and pipe, and a small proportion is used in alloys. The processes of manufacture are relatively simple and they result in little process or engineering scrap. Owing to the relatively large percentage of lead used in pigments, in ammunition and as tetra-ethyl lead in motor spirit, and the loss of bearing metals by wear, there is inevitably a considerable irrecoverable loss. On the other hand, the recovery from storage batteries probably amounts to 80 per cent. after an average cycle of two or three years in motor vehicles, while the cable covering is also largely recovered after a longer period of years.

United States statistics for 1929–1938 show that the recovery of lead as metal produced 1,349,000 tons, one-third of the total production of refined lead during that period, and that in addition, 1,017,000 tons were recovered in the form of alloys, thus saving an equal quantity of virgin metal.

Zinc.—A large proportion (probably 40 per cent.) of zinc production is used for galvanising iron to protect it against corrosion, and none of this is recovered, the zinc being sacrificed for the protection of the so-called iron, but which to-day is mild steel. However, there is a wastage of some 20 per cent. of zinc in the galvanising pot; much of this is recovered as dross, which is re-distilled for spelter or zinc dust. The next largest use of zinc is for brass-making, a considerable proportion of which is recovered and re-used. Apart from this, there is only a small recovery of zinc from the articles in which it appears in the rolled form. The United States statistics show that the recovery of zinc as metal has averaged 11 per cent. of metal production, and in addition slightly less has been recovered in the form of alloys. A considerable loss occurs each year from the use of zinc in pigments.

Aluminium.—There is a considerable scrap recovery of aluminium and aluminium alloys. Process scrap is usually re-melted in the works where it is produced. Engineering scrap (turnings, millings, filings, etc.), which may amount to 50 to 200 per cent. of the weight of the finished article, requires special methods of melting to ensure both a good yield and quality and is usually returned to specialist firms, the secondary metal melters. The segregation and cleaning of the various types of scrap is of great importance.

Old scrap presents a more difficult problem, as it has to be separated into the different alloys, a skilled job requiring experience and the use of scientific methods.

United States statistics for 1929–1938 show that out of a total production of one million tons of metal, one-fifth came from scrap recovery. In addition, about 225,000 tons of aluminium was recovered in the form of various alloys, making the total contribution of scrap to consumption in this period about 35 per cent.

Export of Scrap.—Nothing has been said yet about the export of scrap, but to secure maximum recovery there should be a flow back to metal producing from non-producing countries. The statistics for iron and steel scrap which are fairly complete do show this in a few cases, such as Holland and Switzerland, but the bulk of the transfer of scrap, which averaged 5 million tons a year for 1933–1938, actually took place between steel-making countries owing largely to preparations for war. Under happier auspices the International Scrap Convention established in 1937 might have done much to avoid this uneconomical transfer.

The flow of scrap to the Axis countries in the pre-war years shows how little cause for complaint they had in respect of their free access to the world's metal resources.

Conclusion.—The absence of world statistics on the recovery of scrap makes it impossible to give a comprehensive picture of its full significance. However, it is clear from the data given above that scrap recovery will be of increasing importance as regards the conservation of our metal resources, and that as a major source of raw materials it must be brought into any general scheme affecting them under the Atlantic Charter.

Taking conservation first, the following measures would assist the maximum recovery of scrap and help to diminish wastage of metals :—

1. The salvage of all new and as much old scrap as possible.
2. The adoption of an international convention for marking material made from the main types of alloys to help in their subsequent identification and recovery.
3. Improved methods for segregating engineering scrap of different kinds so as to avoid mixing different metals and alloys.
4. Improved methods for sorting and cleaning old scrap and identifying doubtful material by quick tests.
5. Improved methods for cleaning scrap and getting it into a suitable form for remelting.
6. Arrangements to avoid losses by corrosion when scrap, often finely divided, is kept for long periods.
7. Avoidance of the unnecessary use of alloys which complicates scrap recovery, and the reduction of the number of alloy specifications to the minimum necessary.
8. Improved methods for protecting metals against corrosion.
9. The re-use of old scrap by fabrication and welding.

Turning now to the inclusion of scrap metals in any general scheme for metal supplies under the Atlantic Charter, the first essential is the compilation of international statistics on an agreed basis. Even if these cannot be complete owing to the difficulty of including old scrap which is re-

used by works internally and so-called runaround scrap such as bearing metal, which circulates internally and therefore does not come into account, it should be possible to collect data for all process scrap, engineering scrap, or old scrap which reaches the market, so as to see to what extent consumption in each country can be met from virgin metal or from scrap.

The need for such statistics was emphasised in the following passage from the Report of the National Resources Board of the United States appointed by President Roosevelt in 1934 :—

'The subject of scrap is the great blind spot of the world's metal economy. Despite the importance of secondary metals no statistics of an international character can be had. The United States is the only Government compiling figures of secondary metal production. The present annual statistics of the Bureau of Mines should be established on a quarterly or monthly basis and expanded to include stocks and consumption as well as output. This is one of the most constructive steps that could be taken for stabilisation of the metal industries. Until the importance of scrap is recognised, effective adjustment of supply and demand in the metal industries will remain difficult or impossible.'

This was written in 1935 with special reference to the United States ; to-day in the light of the Atlantic Charter it has a much wider significance.

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Dr. David Williams
Mineral Resources of the U.S.S.R.

SINCE the inception of the First Five-Year Plan in 1927 the U.S.S.R. has made great strides towards the goal of domestic self-sufficiency in mineral supplies. Under the ægis of central authorities such as the Institute of Geology and Prospecting and the Academy of Science, thousands of enthusiastic geologists have been engaged in the search for new resources, playing an essential rôle in the industrial revolution which has swept through the Soviet Union. Although vast areas still remain to be explored, probably no country is more nearly self-supporting, and certainly none has brighter prospects of industrial and agricultural expansion in times of world peace. To some extent this favourable position is due to methods of national economy, whereby commercial considerations are subjugated to national expediency.

Most of the important deposits of metallic minerals lie within the ancient and deeply eroded mountain chain which extends along the Urals and then swings eastwards through Kazakhstan into Central Asia, or among the younger and more rugged mountains of the Caucasus and Eastern Siberia. Although great deposits of iron and manganese ores occur in the Ukraine, the main sources of Russia's mineral wealth are still many hundreds of miles from the present battlefields.

Russia's immense reserves of coal, iron, and petroleum afford a sure basis for industrial progress, and in each of these three vital commodities she is capable of long maintaining a surplus output.

Iron and Ferro-Alloys.—Even omitting the astronomical tonnages of comparatively low-grade quartzitic iron-ores of the Kursk district, the Soviet reserves of *iron-ore* have recently been estimated at more than 10,000 million tons, surpassing those of the U.S.A. In 1940 Russia produced 28 million tons of ore, about two-thirds of which was raised from the Ukraine deposits of Krivoy Rog and the remainder largely from Magnitogorsk and elsewhere in the Urals. Among other extensive deposits are the oolitic, brown iron-ores of the Kerch Peninsula in the Crimea, the magnetites of the Kuznetsk region, and the hematites of Far Eastern Siberia. With such huge resources of iron-ore the Soviet Union is capable not only of fulfilling her own internal demands, but also of contributing a generous export supply.

Among the ferro-alloys Russia has been, within recent years, the world's largest producer of *manganese* and *chromite*, supplying respectively about a half and a quarter of the total world output. In 1936 manganese resources were computed at over 700 million tons, sufficient for more than 200 years output at recent levels, the chief ore bodies being the two famous deposits of Nikopol in the Ukraine, and Chiaturi in the Caucasus. Although the output of chromite has increased steadily during the past decade, it has recently been used almost wholly for domestic requirements of ferro-chromium and chromium

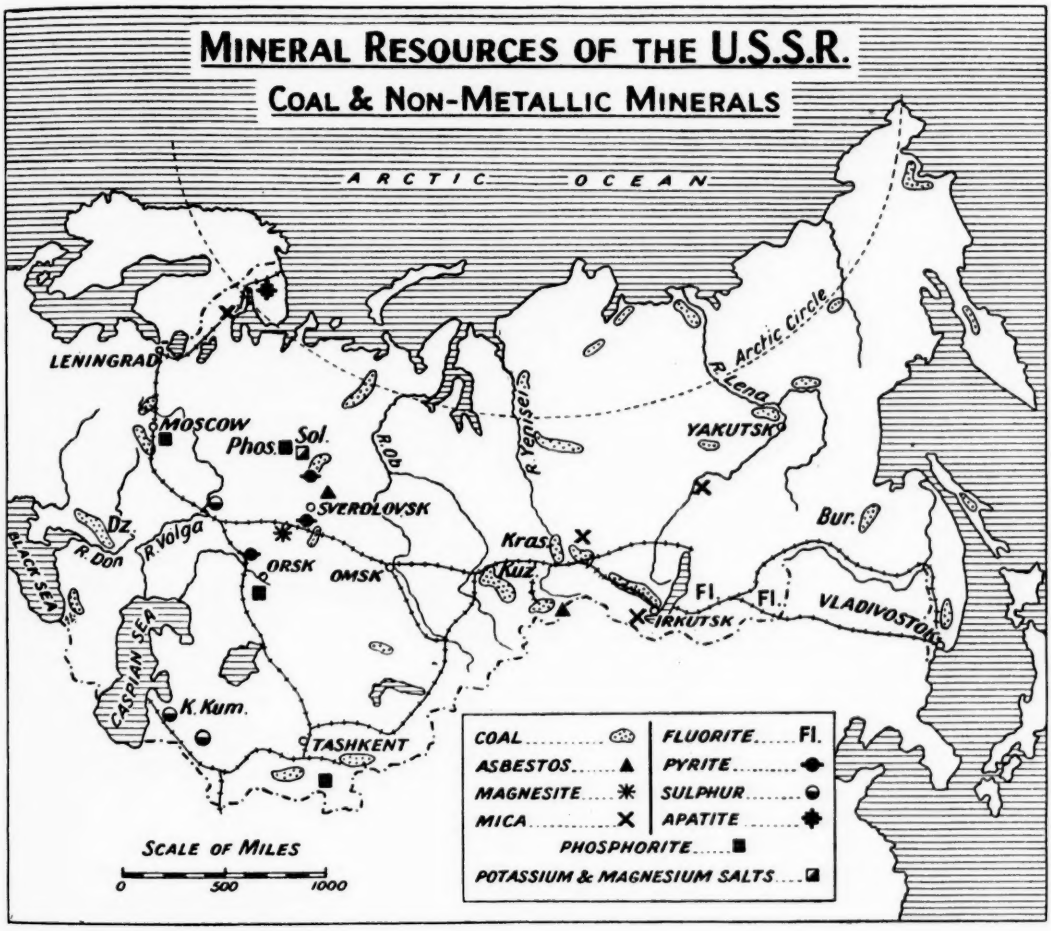
chemicals. The principal mines lie near Sverdlovsk in the Central Urals. Unless fresh discoveries are made Russia may be compelled to retain her entire production of chromite for home consumption.

Russian supplies of *nickel* have so far proved to be inadequate, but by exploiting several extensive low-grade nickel silicate deposits in the Urals and nickel sulphide bodies in the Kola Peninsula and in Northern Siberia, she may well become independent of imports in times of peace. According to present information, however, it is unlikely that the U.S.S.R. will ever raise a surplus supply of nickel.

For *tungsten* and *molybdenum* the Union relies very largely upon imports. Both metals occur in widely separated localities throughout European and Asiatic Russia, many promising discoveries having been reported. Workable deposits of tungsten-ore (wolfram) have been located in the Transbaikal area, but no great reserves are yet claimed. Much is expected from the new tungsten-molybdenum concentrator at Tyrny-Aus in the heart of the Caucasus, and from other mills erected for the recovery of molybdenum in Kazakhstan and E. Siberia. It seems reasonable to infer that the U.S.S.R. will eventually become self-sufficient in molybdenum, though the outlook for tungsten appears to be less promising.

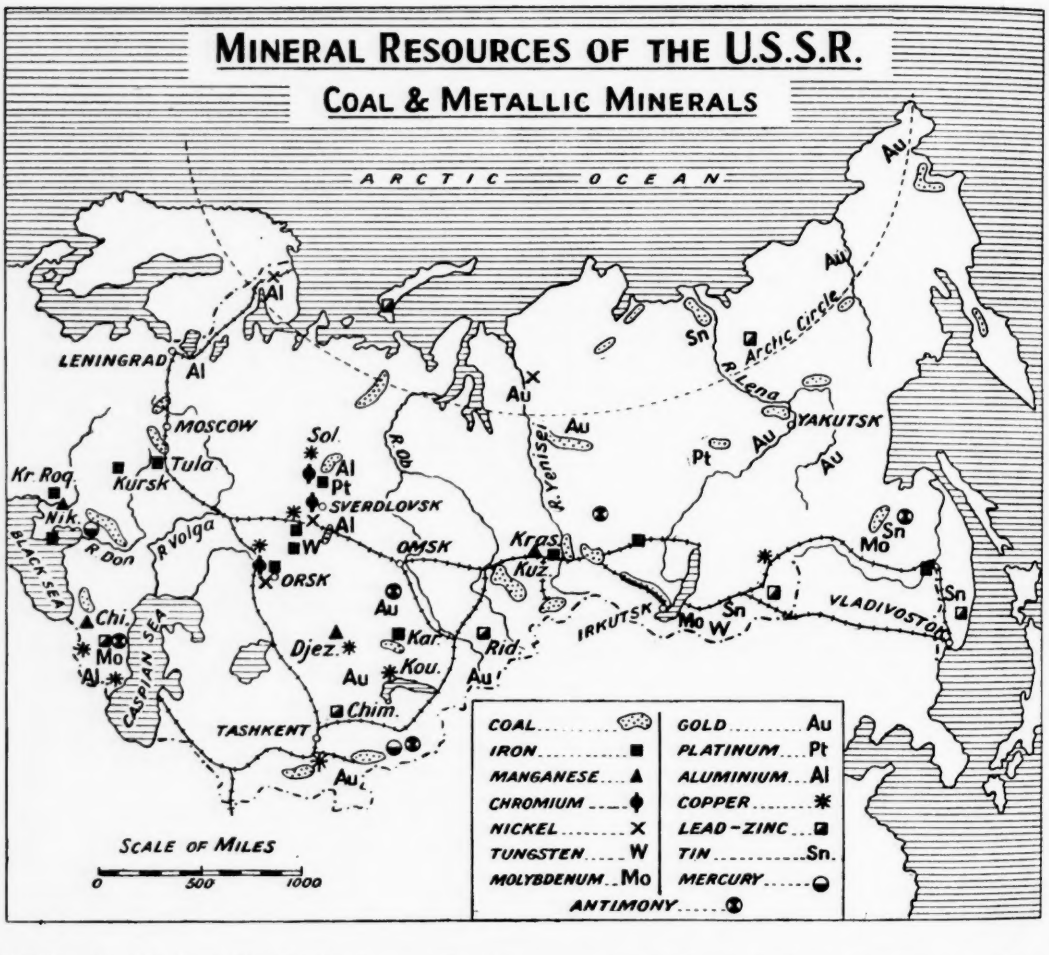
Non-ferrous Metals.—Russia has for long held either first or second place among the world's *platinum* producers, and although full statistics have not been available lately, there is little doubt that she will continue to be a foremost exporter of the metal. Until a few years ago *mercury* was mined only at Nikitovka in the Donetz basin, but quicksilver deposits have now been opened up in the Kirghiz, and apparently the Union's mercury supplies and demands are roughly balanced.

Aluminium was first produced by the Soviets on an industrial scale in 1932, and although production failed to reach the projected output the amount of metal extracted from bauxite had risen to 55,000 tons in 1940. The hope that a total production of 200,000 tons of aluminium would be attained in 1942 cannot materialise, for some of the chief hydro-electric plants (Dnieper, Volkhov near Leningrad, Kandalaksha in Karelia) are now in enemy hands or are gravely endangered. In favourable circumstances, however, there are good prospects of achieving and even exceeding this figure, though the output for some considerable time to come will doubtless be required for domestic needs. Bauxite reserves, sufficient for several decades, are estimated at 45 million tons, the largest and richest deposits lying in the Urals to the north of Sverdlovsk.



Immense quantities of nepheline and alunite are also available for the production of alumina and aluminium, and already plants have been erected for treating nepheline tailings from the apatite works at Kirovsk in the Kola Peninsula. The potential supply of nepheline, which contains about 33 per cent. of alumina, must exceed 100 million tons.

Although Russia produced more than 100,000 tons of *copper* in 1938, she also had to import approximately two-thirds as much. Most of the copper smelted hitherto has been won from



Uralian deposits (notably Degtiarsk, near Sverdlovsk), but the greatest ore reserves are in Central Asia, at Kounrad and Djhezkazgan near Lake Balkhash, and at Almalyk in the Tashkent area. The estimated resources of copper (metal) have been placed at 16 million tons, and although this may be an optimistic figure, it is clear that when the mines and smelters are working to full capacity there will probably be no necessity for the Union to import any copper from abroad.

Production of *lead* and *zinc* has been steadily increasing during the past twenty years. Although the position with regard to lead is not yet satisfactory, the zinc output is probably ample for domestic uses. During the three years preceding the outbreak of war the imports of lead and zinc averaged approximately 30 and 2 per cent. respectively of the country's total requirements of those metals. Russian reserves of lead and zinc have been calculated at 11 per cent. and 19 per cent. respectively of the world totals, the chief deposits and refineries being in the Caucasus (Sadon), and in the Kirghiz and Kazakhstan mountains (Ridder, Chimkent, Sokolny, and Belousovsk). In view of future demands there appears to be small likelihood of the Union producing a surplus of either of these two base metals.

Up to 1937 Russia was almost wholly dependent upon imports for both *tin* and *antimony*, receiving annually about 12,500 tons of the former and more than 2,000 tons of the latter. Apparently the most promising of the tin-bearing areas yet prospected lies in Eastern Transbaikal, but the recorded tonnages of proved ore are not large. Reports suggest that tin smelters may soon be operating in Yakutia and Tetiukhe, in Eastern Siberia. Unless tin substitutes are developed, or new deposits are discovered, it is inferred that the U.S.S.R. must continue to rely largely on imports of the metal. Valuable deposits of antimony ore have been discovered at Kadam Djai in the Kirghiz and in Central Siberia, and it seems justifiable to expect that Russia will eventually be able to meet her own moderate peacetime needs of antimony.

Statistics for *gold* production are a state secret, but it is certain that the Union has adequate resources of this precious metal of enigmatic worth.

Non-Metallic Minerals.—Russia's position with regard to these minerals is stronger than that of any other country.

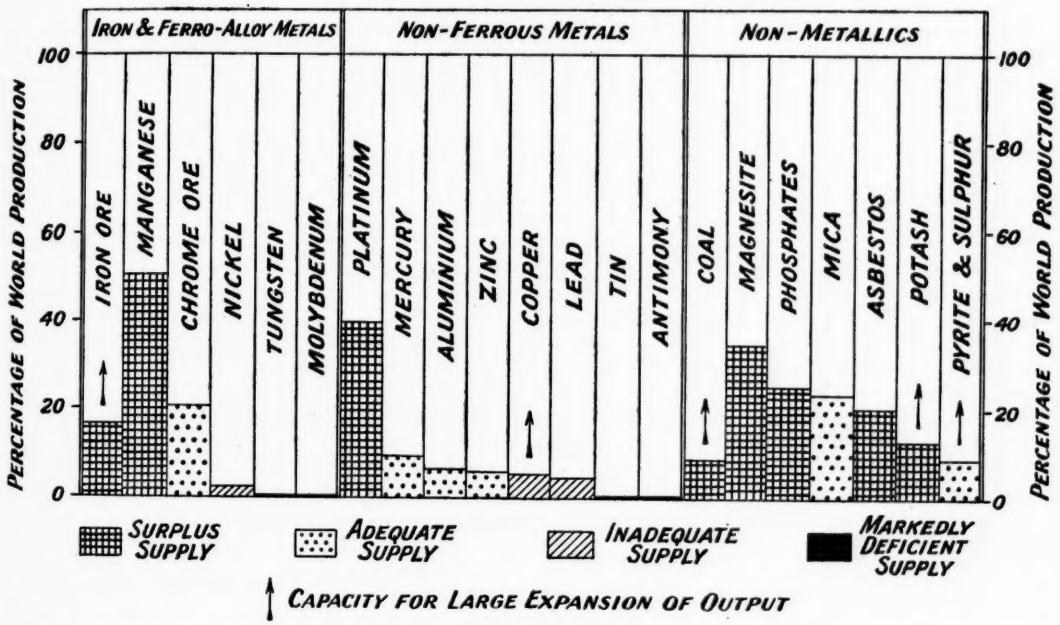
In recent years the U.S.S.R. has been the world's largest producer of crude *magnesite*. The Satka deposit, near Cheliabinsk in the Central Urals, alone yielded more than 800,000 tons of the mineral in 1937 ; including nearby deposits the reserves are reputed to be about 250 million tons. Hitherto most of the output has been utilised for refractory purposes, but some magnesium metal is also manufactured from Satka ore. Although the production of metallic magnesium was less than 4 per cent. of the world total in 1940, the potential output is enormous, for there are inexhaustible supplies of raw materials from which the metal can be extracted, notably the rich carnallite ($KMgCl_3.6H_2O$) deposits of Solikamsk in the Western Urals, brine from various salt lakes, and the Satka magnesites.

Russian geologists claim that the prospected *phosphate rock* deposits of the U.S.S.R. now exceed 60 per cent. of the world's resources. Near Kirovsk, in the Kola Peninsula, phenomenal bodies of apatite, discovered in 1926, have recently been yielding more than 2 million tons of ore annually, with reserves for another millennium ! The principal phosphorite deposits occur in European Russia, in the regions of Kirov (Phosphoritnaya) and Moscow (Egorjevsk), but an extensive and favourably situated field near Aktiubinsk in N.W. Kazakhstan is being developed to supply agricultural fertilisers for western Soviet Asia.

No details of *mica* production have been issued since 1935, when the Union held second place in world rank. The muscovite pegmatites of the Mama-Vitim area in Eastern Siberia and the Chupa Fjord district of Karelia, and the phlogopite veins of Slyudyanka at the western end of Lake Baikal, are doubtless capable of providing adequate supplies for domestic consumption. For many years the Russian output of *asbestos* has only been exceeded by that of Canada. The yearly production of chrysotile asbestos from the well-known Bazhenov field, near Sverdlovsk, is roughly 100,000 tons, the total reserves amounting to more than 30 million tons. It is unquestionably one of the largest and most productive asbestos fields in the world.

MINERAL PRODUCTION OF U.S.S.R.

ACCORDING TO LATEST PRE-1940 ESTIMATES



The region of Solikamsk, on the western slopes of the Urals, has long been known for its brines and salt works, but it was only after deep boring commenced in 1925 that the remarkable deposits of *potassium* and *magnesium salts* (sylvinite and carnallite) and the enormous masses of *rock salt* were thoroughly investigated over an area of some 700 square miles. Production started in 1932 and within five years the annual output had risen to over 2 million tons of crude salts, and large quantities were being exported. Solikamsk reserves are claimed to represent about 80 per cent. of the world's resources, consisting of 15,000 million tons of potash salts, 18,000 million tons of magnesium salts, and scores of thousands of millions of tons of rock salt. Even the famous Stassfurt deposits of Germany are dwarfed !

In 1938 Russia was among the leading producers of *pyrite*, with a tonnage approaching one million, derived chiefly from the Uralian cupriferous bodies (especially Degtiarsk) and from various coal mines. Expeditions to the Kara Kum desert and the Gourdak range in Turkmen territory, east of the Caspian Sea, have discovered

huge supplies of *native sulphur*, comparable with the great Sicilian deposits. These Turkmen occurrences are likely to be the main future source of sulphur, except in areas where it is being recovered during the treatment of sulphide ores.

Adequate resources of other minerals, such as *graphite*, *fluorite*, and *gypsum*, are known to exist within the Union.

The development of mineral resources in the U.S.S.R. during the past fifteen years has far surpassed anything formerly achieved in a like period of the world's history. Sceptics may doubt the validity of some of the Russian estimates of ore reserves, but it should be recalled that vast territories still await detailed investigation and that the actual resources may well prove to exceed even those now claimed. Despite the present marked deficiency in a few metals, notably tin and tungsten, it is reasonable to suppose that Russia will eventually become almost entirely self-supporting and be able to export large quantities of coal, iron, petroleum, manganese, platinum, magnesite, phosphates, asbestos, potash, and sulphur. Unbiassed minds cannot doubt that Russia, with her immense natural resources and man power, has much to offer in the cause of world progress and welfare, and not least a share in her abundant mineral wealth. Any plans, such as those envisaged in Clause IV of the Atlantic Charter, which are concerned with the future access to the raw materials of the world must surely stress the importance of the Soviet Union, whose potential mineral supplies probably exceed those of any other country.

Saturday, July 25: Afternoon Session

Address by

Rt. Hon. Sir Stafford Cripps, P.C., M.P.,

Chairman

I CONSIDER it a great honour that I should have been invited to preside at this session of the Conference on ' Mineral Resources and the Atlantic Charter,' and it is a welcome relaxation in the midst of the urgent activities of the war to be able to spend this afternoon with a body of scientists who are giving consideration to the vast problems that will confront our civilisation when the present tragic chapter of world history has been closed.

My association with science and with scientific personages has been a long one—ever since I deserted the attractions of a Science Scholarship at Oxford for the even greater attractions of working for three years under the late Sir William Ramsey at University College, London. Throughout my years of professional experience at the Bar—now finally closed—I was continually engaged in scientific cases of the widest variety and I had many opportunities of working with inventors and expert witnesses in every branch of science. Some of you may perhaps think that such an experience does not give a contact with what is best in the scientific world ; but whatever else it does, it certainly brings a realisation of the wide ramifications of science in our modern ways of life, and of the great part which scientists must play in the progress of our civilisation.

The scientific lawyer is continuously trying to interpret to lay minds the contributions of science to industry and to explain the relation between scientific theory and production. Sometimes his efforts entail an appreciation of the most complicated scientific facts—as, for instance, in the case of the gyro-compass—and often it is necessary for him to concert with the experts' long scientific investigations and researches. I well remember one case in which a special establishment was set up for carrying out these researches and many tens of thousands of experiments were carried out in order to try and ascertain the true theoretical basis for what, upon the face of it, appeared to be quite a simple invention. All this experience brings an understanding of the part which research and pure science plays in our life to-day.

The growth of technical knowledge and personnel has brought a problem to our democracy which is as yet unsolved. It was truly said two years ago by a group of American professors that ' technical invention and progress had outstripped social and political invention.' We still have to devise some means by which we can fit into our democratic organisation the technical expert and the technician so as to make the most of their contribution.

I do not personally believe in government by specialists, but government without the aid of specialists is to-day an impossibility. We do not want to see our Parliament composed of experts and technicians, for Parliament should have what has sometimes been termed the ' common jury ' type of mind—the mind that can form a general judgment upon problems of wide political import, though often that judgment must be formed upon the basis of scientific evidence or technical knowledge.

The ever-widening sphere of our knowledge, with the necessity which it imposes for a more and more narrow specialisation, renders it increasingly impossible for any single individual to survey accurately the whole field of those influences and considerations which must determine our policies.

That scientists will and must play a most vital and distinguished part in the construction of the post-war world is certain, but we still have to devise suitable methods by which their contribution can be facilitated and can become most effective. It is good to observe that science is no longer regarded by the people as something divorced and separate from their general life. The connection between science, economics and politics is beginning to be realised, and how close that connection must be is well demonstrated by the range of questions which have been under discussion in the course of your present meetings and which were dealt with at the British Association meetings on ' Science and World Order ' in September last.

The title of the present series of meetings brings together the scientific facts as regards mineral resources and the political objectives laid down in the Atlantic Charter. This Charter was an at-

tempt to express in general and easily understood terms the direction in which the political leaders of the democracies envisaged world progress after victory had been won and freedom of spirit and of action had been restored to the peoples of the world. Hitherto, no more precise definition of those objectives or of the means by which they are to be obtained has been possible, but it is clear that in their application a multitude of questions will be raised—political, economic and scientific—which will require the best brains of the world for their solution. A number of America's leaders have recently made statements expressing their views as regards some of the implications which arise out of the Atlantic Charter, and I would like to remind you of a few of their phrases in order to indicate the line on which they are developing the fundamental principles of the Charter.

President Roosevelt.—'The basic things expected by our people of their political and economic systems are simple ; they are :

Equality of opportunity for youth and for others.
Jobs for those who can work.
Security for those who need it.
The ending of special privilege for the few.
The preservation of civil liberties for all.'

Mr. Cordell Hull in his speech of Thursday last has said : 'The pledge of the Atlantic Charter is of a system which will give every nation, large or small, greater assurance of a stable peace, greater opportunity for the realisation of its aspirations to freedom, and greater facilities for material advancement. A vast fund of resources will be released for each nation to meet the needs of progress, to make possible for all its citizens' advancement towards higher living standards, and to invigorate constructive forces of initiative and enterprise.'

Mr. Henry Wallace.—'No nation will have the God-given right to exploit other nations. Older nations will have the privilege to help the younger nations get started on the path of industrialisation, but there must be neither military nor economic imperialism.'

Mr. Sumner Welles.—'Given sound national policies directed toward the benefit of the majority and not of the minority and real security and equality of opportunity for all.'

Mr. Milo Perkins.—'The job of the future will be to build up a mass consumption great enough to use this mass production. This will require a bold and daring use of long term credits by every enlightened Government of the world. Governments must enter fields where private finance cannot enter.'

Hon. Dean Acheson calls for united action by all nations, correlating for this purpose international and domestic measures, to expand production, employment and the exchange and consumption of goods.

The Foreign Secretary in his remarkable speech has welcomed these statements by American leaders in these words : 'It is, therefore, most encouraging to note that in the United States of America the President himself and a number of leading statesmen have repeatedly expressed a determination to work for a world in which each country shall be given an opportunity to develop its own life and its own resources to the benefit of all. In this task our American friends can be sure that we shall be ready to meet and work with them all the time and all the way.

'There are many complicated and difficult matters to be worked out after the war ; they will require not only hard work and much goodwill, but also political invention of a very high order. For, when new political relationships develop, novel forms of political instruments, or working arrangements, are required to give expression to them.'

These statements are the beginnings of an interpretation of the generalities of the Atlantic Charter into the more detailed objectives which policy makers must have in view in working out their programmes. We should all of us agree with the broad objectives set out in these speeches, especially those of President Roosevelt, and it is encouraging to realise that there is such a body of leaders in America with whom we shall willingly collaborate along the paths which they indicate. But the implication of these simple phrases is tremendous both from an economic, political and scientific point of view, and prolonged and careful study will be required to devise the ways and means by which the objectives can, in practice, be gained.

It must not be imagined that we in this country are behindhand in thinking out these problems. A great mass of research and investigation is under way both in Government circles and amongst non-official bodies and individuals. Your own activities in this direction are a most valuable contribution, in a period when public opinion is slowly being formed on these questions of the future. But beyond these technical investigations there is another aspect of this problem which must never be lost sight of.

We may make the most careful plans, work out the most detailed methods, call in the help of scientists, economists and politicians, but all this will be of no avail unless there is in the peoples of all nations a determination to succeed, a spirit of co-operation and a ruthless insistence that we should make the common good of humanity the over-riding inspiration of our policies. We are fighting for a moral and not merely a material issue. Though our plans must be scientifically prepared there must be behind them the inspiration of our most deeply religious convictions. The magnitude of our task calls for the utmost of our idealism.

If we were to drop back into the old competitive struggle between nations or between corporations in the attempt to win national monopolies for world resources, then no planning could succeed. Rival plans would be formulated and the more elaborate they were the greater and more destructive would be the rivalry between them. One thing is sure, that the United Nations must, at the end of the war, undertake international regulation of the production and distribution of essential raw materials, both in the interests of the immediate rehabilitation of the devastated countries as well as with a view to attaining that steadily rising standard of living throughout the world which is one of our objectives. It is too early as yet to lay down finally the form that such a regulative system should take. This is one of the matters which requires exploration and which

must be worked out by common agreement amongst the United Nations.

I am very glad to see upon your agenda for to-day the discussion of a project for an International Resources Organisation which would mobilise all the knowledge available in the world concerning raw materials and natural resources and also of the technique of their use. I am certain that your discussion and your conclusions on this matter will be of great help to those who will be charged with the work of agreeing upon some such organisation ; for it is certain that the world can no longer afford—as indeed we have found in our war effort—to leave this great question of natural resources and their utilisation to the haphazard methods of individual action and economic nationalism.

Science in its search for and development of knowledge has long exemplified the international and co-operative side of human activities. There is indeed a healthy spirit of competitive achievement in the scientific field, in the sense that every scientist would like to see his own nation in the forefront of scientific research and development. But all equally rejoice in every fresh advance, in each conquest over the forces of nature, and the results of their achievement are made available for the benefit of all the peoples.

This pooling of knowledge in the field of research, discovery and invention we must now translate into co-operative action in the distribution, manufacture and use of the resulting commodities.

Scientists of all kinds have worked together to discover the mineral resources of the world and to make available to the peoples those resources through the application of the technique of mining and of processing so as to improve the standard of life and comfort of mankind as a whole. Their work has not been aimed in the main at advantaging any particular class of people whether geographic or economic.

It is in the application of the work of the scientists that we have so far failed, in the distribution of the benefits which they have made available.

This war, like its predecessor, is a stage in the efforts of the peoples of the world to readjust themselves to new economic and social conditions, and in that sense it must be revolutionary in its effect upon our civilisation. It will only be by learning the lessons of our past maladjustment and by taking steps to bring our political, social and economic developments into line with our scientific advance, in every field of human activity, that we should avoid the need for yet another revolutionary upheaval after this war is over. This is a task in which all the great nations must co-operate, since to-day, despite all attempts to create autarchies, we are essentially interdependent one on another.

In war we have learned the need, the urgent and vital need, for co-ordinated and planned action if we are to win a victory. We have to-day reached a degree of co-operation between the united nations in the use of raw material resources and in the employment of finished products greater than has ever been reached before in the history of the world. Selfish and national interests have been over-ridden by the insistent demand for efficiency by the fighting peoples. They have learned by bitter experience that co-operation and co-ordination are vital to their survival. Will these be any less vital to the construction of a sound and safe civilisation after the victory has been won? The answer is most certainly 'No.' The difficulties will be no less, the dangers of chaos and confusion will be as great, and the steps which we must take to avoid these must be along the same lines that we have adopted in the war.

For the purpose of war we have built up a great store of knowledge and of practice which we must be prepared to use for the winning of the peace. We must turn our machinery of economic warfare into one of economic welfare.

When I speak of 'we' I am not referring to the British people alone. The whole essence of our action in this field must be co-operation with others both in development and in use. It is therefore essential that problems such as those which are before you to-day should be considered and worked out on the international plane, though we can and must in each nation make our own contribution to the formulation of such policies and plans. The greater we can make our own national contribution, not in preserving benefits for ourselves but in making the whole pool of natural resources widely available for all peoples, the prouder shall we be of our part in the progress of human development.

It is perhaps necessary to say a word as to the difficulty which arises in the minds of some people as to the inter-relation of such an international policy to our own purely national interests. Beyond doubt our first duty as Britishers is to our own people ; so to organise our economy and our resources as to give them a decent and happy standard of life ; to provide them with a good and equal education and to see that none are overpressed in making their individual contribution to our production effort. In a world economy where there was a shortage of natural resources this duty to our own people might compel us to some extent to enter into competition for those natural resources with the peoples of other nations. But the gift of science to the world is that it has shown the way to attain an economy of plenty : it has discovered where the natural wealth of the world is to be found and how it may be transformed into those things which the people need for their living. That knowledge is not the monopoly of any single country, for it has been made available to all the world. There is therefore now no necessity for competition in a world of scarcity to win a decent standard of livelihood for our people. If we make our full contribution to the productive resources of the world, and other countries do the same, there can be enough for all. Two wars have already proved to us what organisation and planning can do to increase our capacity to produce. They have provided a demonstration and a proof of the possibility of plenty which the free peoples of the world must never forget.

Perhaps the most revolutionary element in our war experience is this revelation of an almost unlimited capacity for production in the mutually destructive effort of war, and the growing realisation that this great productive capacity can equally be organised for the purposes of peace, if

only we are so prepared to plan our economy as to make it available.

Neither we nor any other nation must attempt to erect ourselves—as Hitler is striving to do with Germany—into a privileged people living upon the labour and the efforts of other—as he would call them—sub-human peoples. His conception of a ' herrenvolk,' which lies at the root of the Nazi philosophy, is a demand for special privileges and special standards, won not by the productive efforts of the Germans themselves but by their conquest and enslavement of all the neighbouring races. It is against this conception that we are to-day fighting, and the Atlantic Charter is the expression of our conviction that the national resources of the world are now adequate—if wisely used—to provide a decent standard of life for all the peoples, and that all are therefore entitled to their fair share in these resources.

We must not, however, underestimate the difficulties of those words ' if wisely used.' We must frankly admit that in the past we have not succeeded in achieving a wise use of our resources and that therefore we shall need new methods and new organisations if the principles of the Atlantic Charter are to become a reality and not remain, as have so many good resolutions in the past, nothing but pious aspirations.

The road upon which we must make this advance we have to some extent already plotted, and indeed we have actually proceeded along it in developing the plans of the United Nations for their war effort. It is nothing less than the subordination of private and national interests to the public and international good. What is needed now is a common determination amongst the peoples of the free nations to adopt this principle of action by which alone we can attain the objectives of the Atlantic Charter as elaborated by President Roosevelt in the passage I have already quoted and not under any circumstances to revert to the unsuccessful methods of the past. There must be a determined change of outlook from that of competition to that of co-operation. This is not an easy transition to make, but scientists such as those here to-day who have been brought up in an atmosphere of international co-operative development can, I am sure, do much, by their example and by their advice, to create this new and challenging spirit among the free peoples of the world. It is because I realise the important part which you can play in moulding a happier, freer and more peaceful world that I welcome this opportunity of taking part in your deliberations to-day.

Prof. J. G. Smith

International Trade in Raw Materials

CONTRARY to what economists frequently assert, the principal problems of the immediate post-war period will be chiefly political. Their economic aspects will be subordinate. The restoration, therefore, of international trade and access (and equitable distribution to those that need them) of the raw materials everywhere throughout the world will depend in the first instance on political agreements, and only to a secondary extent on appropriate economic organisation.

But there are certain trends in foreign trade especially affecting raw materials which have asserted themselves with vigour in the past and it may be worth while to examine them and discover how we can control them or direct them to our advantage after the present crisis is over.

Historically, international trade is divisible into three main stages in evolution and each has its own special significance.

The first of these, which may be called the period of transit or *entrepôt* trade, was characterised by the importation of goods of foreign origin which were usually exported again untouched or unaltered, a small quantity being retained for home consumption which was paid for by the export usually of home produced raw materials, again small in quantity. This was the early stage of foreign trade, of trade in the sixteenth and seventeenth centuries and its character was that of England's in the middle of the seventeenth century. It is now of comparatively little importance.

At the second stage, raw materials and semi-finished goods of foreign origin required for industry and agriculture are imported, worked up, finished and then exported in their new forms as manufactured products. This we may call the exchange of *manufactured goods for raw materials*, and it is characterised by a reluctance on the part of the manufacturing country to admit finished goods it thinks it can produce itself. The end of the nineteenth century marked the climax of this development, which was small and of little importance until the middle of that century. Speaking broadly, at the end of the eighteenth and for the first quarter of the nineteenth century, the industries of all European countries, except those of Great Britain, worked up only national raw materials for national requirements, the import of foreign raw materials and foreign food-stuffs being insignificant. Consequently, the population of each country, again with the exception of Great Britain, corresponded roughly to the productive capacity of its soil and its mines. Between 1830 and 1880 this correlation was destroyed owing to the development of cheap transport due to the invention of the steam engine ; and the population of the industrialised countries of Western and Central Europe, rich in capital and skilled labour, grew and developed much more quickly than did the production of their national soil and mines. Instead of the latter they utilised raw materials and food-stuffs imported from colonies, dependencies and countries mainly agricultural. They became unable to exist without mass imports of foreign raw materials and foreign products accompanied by mass exports of manufactured goods. Along with Eastern North America they became a world centre of manufacturing industry and of city life. Instead of exporting the labour and capital which was in excess of their own productive power, they specialised in the export of their manufactured products.

Most social thinkers and politicians of the nineteenth and early twentieth centuries considered this system of world economy and of international exploitation as quite normal and unalterable. They assumed that it was, and would continue to be, a sound basis for the future of industrialised nations, and they regarded as

the highest possible system that plan of national economy in which raw materials and the means of subsistence are imported from other countries in exchange for the product of national manufacture exported to those countries. One writer in 1914, after enlarging on the advantages—to the manufacturing countries, of course—of this arrangement, goes on to state that as far as can be foreseen a large interchange between countries of food-stuffs and raw materials against manufactured goods is destined to continue for an indefinite time to come.

But even before 1914 there were signs of the approaching decay of this system and warnings of international economic disintegration were not lacking. As far back as 1880, Russia was contemplating the creation of her own manufacturing industry and had made a significant beginning before her great revolution. The war of 1914–18 considerably quickened the pace of change in many countries, and much movement of industry took place from old centres to the sources of raw materials and of mechanical energy. The comparative cheapness of transport of raw materials was ceasing to exercise the influence it formerly had over the location of industry and manufacturing enterprises. By the 1920's, the altered position was becoming apparent to politicians and administrators, and in 1925 the Balfour Committee on Industry and Trade in its Survey of Overseas Markets analysed the situation in these words : ' Taking the world as a whole, the widespread development of home-manufactures to meet needs formerly supplied by imported goods is by general consent one of the outstanding features of the post-war economic situation.' It went on to express the opinion that this is likely to be a permanent factor and that the tendency is a natural and universal one, inseparable from healthy economic progress and one in no way due to, although stimulated by, the war of 1914–18.

Again in 1928 a German economist, Sombart, drew attention to the radical changes which were taking place in the economic policy of agricultural countries and their serious effect on the national economy of Western European countries. He argued that one result of this would be to compel old capitalist countries to enlarge their agricultural basis either by expanding their production through proper scientific methods or by increasing their rural populations. ' It will lead,' he says, ' to an inverse development of the structure of national economy in European countries, resulting in a relationship between the rural and urban populations such as prevailed, for instance, in Germany in 1882, which then had 40 per cent. of its population rural.' Since about the beginning of the current century, he contends, Europe was evolving in this direction.

If this is so (and there is little reason for casting doubt on the diagnosis), and if no political hindrances are offered to the movement of the mobile factors of production, labour and capital, which was tending to take place before 1939, and will certainly persist in the coming post-war period, countries rich in minerals and agricultural raw materials will export less of their resources and work up more of them at home. This will further reduce the small volume of foreign transit trade that has survived and make serious inroads into the exchange of raw materials for finished products. In this way there may ensue a general reduction in the total volume of international trade (even that, however, is not certain) ; but this cannot be considered as a decline in international *economic* relations. The international exchange of goods according to the formula ' finished goods for products of the soil and mines ' will give place to a situation in which, in the main, products of the soil and mines will be exchanged only for products of the soil and mines of other countries and finished products for finished products. Only under such an international division of labour will it be possible to avoid the increase of population in one country at the expense of another.

It is difficult to form a balanced judgment on this new movement or tendency towards this *third stage* in the evolution of international trade in which each country will, in the main, work up its own raw materials and have its exports largely constituted of finished goods manufactured from those materials. Before a conclusion can be reached or a prediction ventured, it is necessary to investigate how far changes in the factors of the localisation of industry make it desirable to transfer certain industrial activities from one country to another and how far the older industrial countries have lost their former superiority in technique and in the skill of their workers. That has not yet been attempted and will take much time to complete. Certain points, however, attract the immediate notice of an inquirer.

Firstly, in consequence of changes in the technique of production, certain industries are less dependent on skilled labour than before. In such cases it is no longer necessary to move raw materials from undeveloped countries to the older industrial countries for the production of finished goods. But difficulties in marketing the product from countries with a poor local demand and ill-developed commercial services may more than counteract the advantages which would otherwise accrue from manufacture on the site of the raw materials. Again, even if no great skill is called for, the comparative inefficiency of labour in certain Oriental countries may discourage the development of large-scale industries near the raw materials there and capital may not be readily come by in such cases. These disadvantages, however, may be surmounted by political action, if progressive governments think it worth while to do so. Indeed, it is possible to contend that such disadvantages are, in any case, more apparent than real.

Another important point arises from the fact that the significance of supplies of raw materials changes from time to time. Cases of emancipation from what may be called the tyranny of raw materials are not difficult to find. Perhaps the growth of the iron and steel industry in countries like Italy and Japan is a good example. There, the increasing use of scrap has enabled fairly large works to be established. In this way the importance of the presence of iron ore deposits as one of the determining factors in the localisation of the ferrous metal industries is much diminished. The case of Chilian nitrates also is relevant in this connection, although the

large expenditure of fixed capital required for the manufacture of the artificial product has not altogether destroyed the importance of the natural product, and in consequence the Chilian deposits were lately resuming their former importance. But the opposite tendency is, probably, the stronger ; and countries producing raw materials are attracting to themselves, to an increasing degree, the refining and finishing industries in metals. At first only the very early stages of the manufacturing process are performed where the ore is extracted. Very soon after, however, further stages are added, the number depending on transport costs and the increasing value of the commodity in relation to its bulk, as the manufacturing process approaches completion. In almost all the metal refining industries examples are to hand. Zinc in Australia, in Canada and in Mexico, lead in these same countries and in India, copper in South America and in South Africa are only a few selected out of many.

Diffusion of industry may result also from the development of the synthetic production of raw materials ; and the growth of new consuming centres with large populations favours the establishment of industries near to the markets which spring up in the centres of production of raw materials.

When all these factors and others are taken into account, it becomes impossible to pass a simple verdict on this apparent tendency of international trade to enter on its third stage. The problem is a complex one. The only safe conclusion to draw is that the manufacture of certain simple consumption goods is tending to be widespread and to be independent of the localisation of their raw materials, that localisation of the raw materials of the heavier industries may work both ways in determining the localisation of the manufacturing process, thus admitting of considerations other than purely economic ones in the choice of a country's industrial policy, and finally that industrial centralisation in the older countries is losing some of the great extent of the growth it enjoyed at the beginning of this century. If it is permitted to make a forecast—it may well be that the international exchange of goods according to the formula 'finished goods for products of the soil and mines,' which is so important now, will give way to a situation in which products of the soil and mines will, as a rule, be exchanged only for products of the soil and mines and manufactured goods for manufactured goods, but that this will take time for its accomplishment. Then, that peculiar historic phenomenon, the capitalist regime of the U.S.A. and of the older industrialised countries of Europe will appear as a natural but transient phase in the evolution of international economic relations from the comparative simplicity of the days of purely transit trade to the period of the maximum development of world economy and the elimination of the fundamental reasons for international conflict and struggle.

Ultimately, then, access to raw materials not possessed by itself may not be a problem for any country. Indeed, in the past, as long as trade remained reasonably free and markets were open no difficulty or hardship was experienced. But when control schemes were instituted and countries possessing the richest and most accessible supplies began, in the supposed interests of their producers, to regulate the output permitted for sale, consumers rightly felt aggrieved. Even when the control was ostensibly international it was exclusively in the interests of those who owned the supplies in the territories in which they were produced. The peoples of other countries were allowed no voice in the arrangements agreed upon. This is a situation which no great consuming country could be expected to tolerate even though a good case might be made for temporary restriction of output in periods of trade depression. If, therefore, general free trade in, and unrestricted access to, raw materials are not to be restored and, instead, a regulated production and trade in those commodities is contemplated, the regulations must be genuinely international. It will not be easy to embody a system of national production in one of international planning. Perhaps regulated trade linked with cartel agreements and real representation of consumers may provide a solution. If that is so, goodwill and considerations not primarily economic will have to be the foundation of the new international economic organisation.

Dr. W. A. Lewis

Some Aspects of Mining Finance

I WANT to examine for a few moments the processes by which capital is raised for mines, and to consider some social repercussions, especially in the colonies.

The money required for mining enterprise comes to a large extent from the ordinary investor, on whose attitude depends the amount that can be raised and the price that must be paid. His attitude has important consequences. In England the investor regards most mining shares as highly speculative ventures into which he should put only a small proportion of his capital. This for three reasons. First, the amount of ore contained under the ground is always uncertain ; secondly, the prices of most minerals, other than gold, have been subject to the severest cyclical fluctuations, so that the investor is uncertain whether any particular concern will outlive the next slump ; and thirdly, there has been so much fraud in mining finance that the investor is naturally suspicious of small unknown concerns. This last reason deserves special attention. If all element of mistrust could be removed, the small independent mine would find it much easier to raise money in London. The legal provisions relating to company promotion need to be tightened up, and there are those who think that the Government should exercise as strict a control over new issues as is now done in the U.S.A., since the New Deal administration set up the Securities and Exchange Commission. On the other hand, the London Stock Exchange has itself so tightened up its provisions relating to shares to be dealt in on the exchange that broker friends assure me that there can be no repetition of the scandals of the past, and it remains to be seen whether these reforms will prove adequate.

Meanwhile the mining industry has evolved its own method of inspiring the investor's confidence, namely the emergence of powerful finance cor-

porations, standing between him and individual mining companies. These corporations have also non-financial activities : they may give specialist technical advice to, or supervise the operations of the mining companies under their wing ; they may buy stores for them and market their product ; and so on. On the financial side, with which we are concerned here, they have two uses. First, they hold the shares of many different mining concerns, and so spread the investor's risk, at the same time as they make it easier for the mine to raise funds. And secondly, their reputation acts as a guarantee that the mines under their wing are not mushroom concerns, and have the best technical advice and management, so that the public is more willing to buy the shares issued by these mines. This ' grouping system,' as it is called in South Africa, has extended to the rest of the continent. It finds its parallel, though not its duplicate, in the ' managing agency ' system of the Eastern colonies. From the investor's point of view it is a good system, and inspires his confidence. From the point of view of colonial governments it can be a disquieting development because it means that sooner or later an entire colony may find itself in the hands of one or two corporations, themselves dominated by one or two rich men. To this I will return later.

Pass for a moment to consider another aspect of mining finance, the extent to which British mines receive funds from foreign countries. There have been foreign funds in British gold, copper, tin, diamonds and other concerns. The sources of these funds are also significant. For the most part they have come not from the ordinary investor, but from banks and mineral associates. The ordinary investor has taken some little interest in the most famous South African shares, but even in South Africa the earliest monies from France and Germany were predominantly supplied by the banks of those countries ; and the equities of other British mines are not noticeably to be found among the holdings of ordinary investors in foreign countries. Indeed, in America, which from the point of view of post-war finance is probably the only country that needs to be considered, the ordinary investor has had only a limited experience of foreign lending, has confined it mostly to fixed interest bearing securities, and having had his fingers burnt, is unlikely to prove very adventurous after the war. If we want to get money from him for British mines, it will have to be borrowed either by his Government or by ours, acting perhaps through a specially created mining finance corporation. Such money as we have got so far from America has come from magnates like J. P. Morgan and the Guggenheims.

The fact that the foreign funds are highly concentrated serves to reinforce my point that sooner or later the mines in any area tend to pass into the hands of one or two giants, and present an abnormal concentration of economic power. The process is not yet complete, least of all in Malaya, though even there it was proceeding rapidly.

The governments of these territories are thus faced with two main problems. First, the financing of small mines. There are still areas where small scale mining is economical, but the small miner does not easily raise funds. He has no access to the money market, and if he is short of personal capital has to act as a ' tributer,' within the limits of indebtedness allowed by his principals. This has driven two governments, those of Southern Rhodesia and Tanganyika, to set up special funds for financing small miners, and where small scale mining still has a future we may see more colonial governments acting as finance houses, as they already do in agricultural finance, borrowing money in London and setting up special institutions to re-lend to the small concern.

The other problem is more difficult, how to control the big giants. The sanction of private property, if it has any, is the competitive market, whose forces prevent exploitation. When competition disappears, labour is at the mercy of the employer, profits can be excessive, and the whole progress or retardation of a colony may depend on decisions taken at a directors' meeting in London. It is not therefore surprising that recently colonial governments have had to tighten up their controls. Labour conditions, the nature and amount of royalties, deliberate under-development of resources, and the quotas allocated in international restriction agreements are all matters calling for much greater control than there has been in the past. The biggest bone of contention of all is profits. When the colonial peoples realise that in 1937 the Trinidad mines earned in profits three times what they paid in wages to native employees, the Gold Coast mines two and a half times, and the Northern Rhodesian mines twenty times, and when they read of dividends of 100 per cent. per annum, they are apt to get rather sore, to ask why European capitalists are allowed and encouraged to come and take out the principal wealth of their countries, leaving so little in return, and to demand nationalisation, if not expropriation. There are easy answers : profits must be set against losses ; good years against bad years ; and not all mines are as profitable as those of Northern Rhodesia and Malaya. Yet the political trend points surely to the fact that sooner or later awakening nationalisms will compel the colonial peoples to assume control of their own resources. Meanwhile their governments will be driven to increased taxation, and perhaps to experiment with joint public-private concerns, such as those in the Belgian Congo and the Dutch East Indies, where part of the capital is supplied by the government and part by private enterprise.

I can summarise the essence of this paper by asking four questions, which will, I hope, provide food for discussion.

1. What further controls are needed in the London capital market to prevent fraudulent finance, and thus to increase confidence in mining shares ?

2. Is it desirable to have more foreign capital in British mines, and how can this best be done ?

3. How far should independent small-scale mining be encouraged, and how is it to be financed ?

4. What further checks on private mining in the colonies are desirable to prevent exploitation and excessive export of colonial wealth, or, if private mining disappears, what checks on government mining, to prevent waste ?

On the answers to these questions depends the attainment of the objective we have all set our-

selves, namely, that the world's mineral resources shall be developed in the interests of the peoples of the world, and not of a privileged few.

Mr. Arthur Notman

Economic Considerations associated with Aluminium

It would serve no useful purpose, were I well qualified for the task, to attempt in the brief compass at our disposal to duplicate even in outline the exhaustive historical, technical and economic treatment of aluminium now readily available to the scientist, engineer, economist and the general public. There is a wealth of well-prepared material, too large for me to attempt to give credit to the many contributors. There are certain aspects of the extraordinarily rapid growth in the use of this 'infant' among the non-ferrous metals that bear a tragic import for this generation, but which may contribute even greater blessings to future generations. It is to these aspects that I shall confine my attention with the hope that they may prove of stimulating interest to this audience.

Valuable ore deposits can be defined as geological anomalies. Their fortuitous distribution in the earth's crust has often been used to support the claims of the 'have not' against the 'have' nations. Without attempting to argue the justice of such claims, I merely wish to point out that 'peaceful enterprisers' have been welcomed in the past in most of the so-called backward areas of the world. The fact that most of the successes have been scored by the free citizens of the British Empire and the United States cannot be ascribed to the fortuitous distribution of natural resources. Rather must their success be attributed to the fortuitous distribution of natural ability in the world, and to the relative fairness with which these enterprisers have treated the interests of the nationals of those territories in their dealings with them. In fact, on occasion such undertakings have been discriminated against by the activities of rivals at home rather than those from abroad. For example, we have the imposition of the tariff on copper by the U.S. in spite of the fact that the initiative of their citizens was solely responsible for the tremendous development of copper resources in South America, and in partnership with Canadians in Canada and British in Rhodesia.

In the case of aluminium, we shall see later, no grounds for complaint over availability can be advanced by citizens of the 'have not' nations.

If I may speak personally for a moment, the older I get the stronger my conviction that there is no more fruitful source of international friction than a system of tariffs, exchange controls, or other arbitrary governmental restrictions on man's freedom to exchange the products of his labour or his services to the best advantage. Admittedly we in the U.S. have been the world's worst offender in this regard. Having learned by bitter experience, in the days following the Revolution, that such barriers to freedom of trade between the colonies had defeated their object (namely, to recover from the economic exhaustion of the war) they were prohibited between the states by the embodying of the Commerce Clause in the Constitution. Thus was the foundation laid for establishing the largest free trade market in the world. Without belittling the importance of the great natural resources of the United States in the rapid growth of her prosperity in the last 160 years, or that of the freedom of speech, press, religious conviction, and assembly, I am not sure but that freedom of trade within her borders was fundamental to the maintenance of all the other freedoms. Again, after the Civil War, under pressure of debt, we enacted the long series of tariff revisions that in spite of our shift from a debtor to a creditor position following the first World War, finally ended with the passage of the Smoot Hawley Tariff Bill, the 'all time high' of American Tariff Legislation. Thus we became the foremost defender of free trade domestically and the most ardent protagonist of protection internationally. It is said that a house divided against itself must fall. Well, we certainly fell into the deepest depression in our history.

To these freedoms have been added, in the Atlantic Charter, the freedom from fear and the freedom from want as objectives of the United Nations. The fear of being unable to compete successfully is the excuse for tariffs. How can we then in the United States or those of us in the other United Nations reach or support those objectives, if we remain unwilling to extend equal privileges to each other across national boundaries. Seemingly, I have wandered far afield from my subject, but I hope you will bear with me, for I may offend again as I go on.

Although it is the most abundant of the metallic elements, aluminium is no older than the speaker, whereas its sister metals have been known and used for centuries. Yet it has already overhauled three of the four non-ferrous metals known to the ancients, tin, lead, and zinc, and may even overtake copper in the next decade.

Ratios of World Production of Aluminium by Volume in Certain Years to World Production of other Non-Ferrous Metals by Volume

	Aluminium to Copper	Aluminium to Zinc	Aluminium to Lead	Aluminium to Tin
1900	0·05	0·04	0·03	0·23
1910	0·16	0·14	0·16	1·02
1920	0·44	0·47	0·62	2·76
1930	0·55	0·49	0·69	3·97

From *International Control in the Non-Ferrous Metals*, p. 215, published by MacMillan Co., New York, 1937.

The 'explosive' character of its adoption is without parallel. The nearest approaches are found in the sudden expansion in the use of petroleum with the invention of the internal combustion engine, and that of copper with the introduction of electricity. Without the results of these discoveries and their corollaries, the development of cheap sources of power and the

determination of the fundamental laws of electro-chemistry and electro-metallurgy, aluminium might still be the mere curiosity of Louis Napoleon's day, 'silver from clay.'

Man has an insatiable appetite for mobility. He has never had enough or sufficiently rapid transportation. He has continually sought for new materials and new methods with which to satisfy that appetite. The Kaffir boy of South Africa no sooner accumulates a few pounds above his requirements (in the gold mines of the Rand or the copper mines of Rhodesia) than he invests in a bicycle. Man has an equally voracious appetite for news and rapid communication. When my grandfathers were boys, man and his messages were limited to the speed with which horses could travel on land and sailing vessels could cross the sea, and had been for centuries. It is true that crude communication had been expedited in limited areas by visible or audible signals. To-day news flies round the world as rapidly as conversation, while man himself can eat breakfast in London and dinner in New York.

Metals and their alloys have made these things possible, but with all the cruel dangers and sufferings that these phenomena have enabled the forces of evil to inflict upon the world.

The conquest of the air depends fundamentally on the lightness and strength of aluminium and its alloys, and the internal combustion engine. To realise what this has meant in the growth of use it is merely necessary to refer to the fact that, as late as 1913, the world consumed only 80,000 tons of aluminium per annum, while it will probably use close to 2,000,000 tons in 1943, and consume 5,250,000 kilowatts of electrical energy in producing that volume of the metal.

Experts tell us that next to oxygen and silicon, aluminium is the most abundant element in the earth's crust, constituting about 8 per cent. thereof. There can never be any real shortage of the raw material for aluminium production. It is true that the one ore of aluminium from which practically all of the metal produced is now extracted is the hydrate of the metal called bauxite. But substantial deposits of this mineral are already known in all the continents, and though they represent a very minor fraction of the total aluminium in the earth's crust, they, with many more as yet unlocated, doubtless form adequate reserves for even greater requirements than we now envision.

Back of these, there are far greater reserves in more refractory materials which will become amenable to treatment as improved methods are developed. So far the world has never yet failed to find ore deposits from which to satisfy its demands for any metal, even gold. Indeed certain prophets of disaster, among them Hitler, who has none of his own, profess to believe that that demand has at last been satisfied and that gold will no longer play an essential rôle in world economy.

Important mining areas have far outlived the most optimistic estimates of the engineers concerned with their original exploitation. One might even safely add those of their more imaginative promoters. For example, in the case of copper, no important copper producing area in the world, and by that I mean any that has contributed as little as 1 per cent. of the world's total supply to date, has yet been exhausted. Some have reached economic exhaustion because they can no longer compete with cheaper sources of supply. They remain a potential reserve awaiting man's ingenuity to devise cheaper ways to extract the metal, or his willingness to pay more for it. We may recall that Cyprus and Rio Tinto in Spain were worked for copper in the days of the Phœnicians. The latter district has been almost continually productive throughout history. In Cyprus the mines were closed down at times because of economic exhaustion, as is the present case of your own mines in Cornwall, but only to be revived later by improvements in technology which rendered them again profitable. Similarly the Manfeld Kupferschiefer in Germany were first worked in 1250. They are economically exhausted now and have been for several decades past, but production has been maintained, and pushed to the limit with Government subsidy, because of Germany's growing need for copper with the world's supply closed to her.

Aluminium is an acceptable substitute for copper in many uses in the electrical field and elsewhere. For that reason and because of its other peculiar properties, Germany has been extremely active for the past thirty years in the development of aluminium and its alloys. That development made possible the rapid growth of the Luftwaffe and formed a corner stone of Hitler's ghastly gamble to enslave the world.

There is no reason to believe that, if necessary, the United Nations with their combined resources of free men and materials cannot ultimately build and man 200,000 fighting and bombing airplanes per year, and more if needed. Very soon one plant alone in the United States will be turning out one four-engined heavy bomber every hour, 24 hours a day, 8,760 per year. The United States alone has turned out 5,600,000 automobiles in a year of peacetime, with merely profit and man's desire to get somewhere else in a hurry as incentives. If our Allies can hold out a little longer, and I feel sure they will, help will be coming in terrifying volume of which Lubeck, Rostock, Cologne and Bremen were a mere token.

What of the peace? and what has aluminium to contribute to it? First, let me say that the war will be fought in vain if we cannot win the peace. Second, that I believe that we in the United States made every wrong choice whenever and wherever choice was offered after the last war.

To win that peace, our political and industrial leaders must cease catering to the fears of our peoples, and promising protection from 'more able,' 'more fortunate,' or 'less enlightened' competitors. We in the United States started with the need of protection for infant industries.

When the infants became thriving giants we had to find some other argument. We set up the slogan that foreign competition was unfair, with the old 'clichés' of the 'full dinnerpail,' 'breechclout labour,' relative standards of living, etc. We learned recently, after passing from the status of debtor to creditor nation, that tariffs not only outlawed foreign competition, but also outlawed foreign debts, excepting to the extent

that they might be paid with gold, rubber, tin, coffee, tea, silk and a few other minor commodities which we do not produce to the extent of our needs.

Having failed to balance our trade with the world by these limited exchanges, we continued to export without equivalent imports, and took our pay from the proceeds of reckless capital loans to the rest of the world. Of course, it was easier to sell foreign bonds to the American public than foreign equities, because of their seemingly greater security, and their steady income. The excessive coupon rates added to their allure instead of sounding the warning they should have.

Almost overnight we decided that neither the original debts or the more recent loans were sound, which was true so long as we insisted on selling more than we bought and were unwilling to make long term foreign investments. So we turned our back on world trade and our debtors and announced that we would at least defend our internal market from the depredations of any unfair foreign competition, and passed the Smoot-Hawley Bill. Retaliations were quick to follow, bringing with them a collapse of world trade and deep depression. It was a strange attitude of mind for a people who had evolved the philosophy of mass production and sold automobiles profitably all over the world in spite of unfair competition, adverse tariffs, etc. But fear of competition, like its other manifestations, is the very antithesis of that self-reliance and confidence we like to regard as characteristic of free men.

When isolationism failed to bring prosperity, we wondered whether it was merely foreign competition that was unfair. Perhaps domestic competition was equally unfair, and could and should be prohibited by governmental fiat. There were too many 'chiselers' in business and industry, and so under the codes of the N.R.A. we proceeded to ban them too. In a more robust day they were known as 'tough competitors.' Fortunately for us all, in that we are first of all consumers from the day we arrive in this 'vale of tears,' and are successful in raising our standards of living only to the extent that we are able to increase the amount of goods and services that we secure in exchange for our own, the Supreme Court declared the N.R.A. unconstitutional. As a friend of mine put it rather wittily, had it not been for the Court, competition would have been relegated to the field of sports, and who knows but that it might have been ultimately barred from that field also, because some man might enter a race and run as hard as he knew how and beat someone, which would be eminently unfair.

No doubt many of you feel that tragic mistakes were made on this side of the Atlantic also, after 1918, and are hardening your resolution to see that they do not happen again. To accomplish this the United Nations must preserve their unity in peace as in war. The fears of selfish interests of our nationals cannot be permitted to disrupt it. They must be led to see that their own intelligent self-interest demands its preservation.

We still have our isolationists over there. Although they took cover on the seventh of last December, many of them will reappear the day of the Armistice. What can we do about them?

It should be plain to every thinking person in the world that two of the prime functions of government are first national security and second the maintenance of law and order. To attain united national security we must and will purge the world of the Axis gangsters. To maintain law and order we must maintain a world police force. No one would seriously think of trying to run London, Moscow, Chunking, Melbourne, Capetown, Buenos Aires, Rio de Janeiro, Montreal, or New York, to say nothing of whole countries or continents, or the world, without a police force. Perhaps aluminium and the internal combustion engine have, for the first time in history, made the policing of the world possible without armies of occupation.

I am sure that the seeming necessity for such armies as a police force lies at the bottom of much of the isolationists' thinking in America. Maintenance of a striking Air Force in the British Isles, in the presently enslaved areas of Holland, Belgium and France, in Poland, Czechoslovakia and Western Russia, in China, Siberia, the Philippines and the Americas, under United National control, could do the job. Such forces, while internationally controlled, could be recruited from nationals of the areas in which they were located with token representation from others. It would be practically impossible for any would-be disturber of the peace to start building aeroplanes, submarines, or making munitions without the knowledge of a small but effective intelligence force strategically located. If and when they did, the United Nations would serve public notice on them, that if they did not stop immediately, on a certain date they would destroy the plants by attack from the air, warning citizens to evacuate the area prior to that date. Probably it would not be as simple as it appears to the lay mind, although most laymen do know a little something about police problems.

With trust and confidence in each other and a determination that the proven gangsters of the world shall not, under any circumstances, be given access to arms, under threat of immediate and total destruction of all their real property, law, order and peace will be within our grasp, on wings of the very metal which made total war possible.

Such a programme could immeasurably lighten the burden of essential military expenditure, and enable us to devote our energies to the real objective of civilisation, making the world a happier abode for the common man. It could happen here and now for the world of our children, and our children's children.

Mr. O. W. Roskill

Planning and the Mineral Industries

1. In the inter-war period there was an immense increase in the influence of international trade. Not only were metals no exception to the general trend—they rather led the way. Among metals such cartel agreements were primarily directed to control of prices. With a few exceptions 'control' meant maintenance of prices at levels acceptable to the higher cost producers who were

generally unwilling to participate in such schemes on any other terms. With the leading exception of tin such agreements were generally made between the chief companies rather than between governments, but even when governments were concerned, there were 'outsiders' who were generally able to benefit from the agreement through avoidance of adhering to it.

2. The war has drawn attention—if it needed drawing—to the inefficiencies of the distributive machine. People are asking why Cornish vegetables should be sent up to London for marketing and down again from Covent Garden to Wiltshire. Several schemes have been introduced to ensure that distributors drew their supplies only from producers in their own region. Quite a number of international cartels recognised this long before the war and achieved economies in distribution by dividing markets between leading producers. The existence of the British Empire and the imperial trade policy pursued since the Ottawa Conference encouraged this trend. In many cases where Britain and Germany were leading exporters (e.g. nitrogen fertilisers) Britain got the Empire market and some others—e.g. Portugal and Germany—got Europe and the lion's share of the non-Empire countries overseas. Division of markets was not, in general, a feature of cartel agreements in the metal trades. There is much to be said for it as soon as ever the first steps are taken towards the abandonment of a *laissez faire* economy. Costs of transport and distribution are almost invariably high in relation to production and one of the first objects of planning should be to reduce them.

3. The London Metal Exchange has a great tradition, and under conditions of free buying and selling performed its functions with an efficiency probably unequalled by any other commodity exchange. But for some years before the war the physical quantities of metals actually bought and sold on the exchange were dwindling, and its functions became increasingly to provide a means of hedging against price fluctuations. The bulk of the copper, not only in this country but also in Europe, was sold direct to consumers by producing companies or their sales agents. We live in a world of controlled prices to-day and there are many who fervently hope that after the war we shall return to a position in which prices are determined by the interplay of supply and demand on a commodity exchange. If, however, the post-war period sees the introduction of widespread planning of production and consumption, then it seems to me that planning of distribution must also follow. A central international authority would examine the actual potential world supply position and the requirements of the various consumers and decide on the allocation of, say, copper to Great Britain and to India. While the copper industry, both producers and consumers, may be represented on or in a position to make representations to such a central international authority, it is very doubtful whether they would be the arbiters of policy since questions affecting many other industries and general questions of social and economic policy (such as electrification projects) would require to be settled in relation to any decision on copper alone. The copper producing industry would, however, probably be responsible for making the requisite quantities and qualities of metal available at the appropriate consuming works when required—in other words, would be responsible for production and distribution up to the manufacturers.

4. In discussing the stage up to which the raw material producer should be concerned with distribution I cannot allow myself the luxury of entering into a discussion on the time-honoured question of what is wrought copper (particularly since I would not like to cross swords with the Customs and Excise), but there is one notable trend to which I may draw attention. In the past there has been a marked differentiation of interest between the producers of raw copper (and other unwrought non-ferrous metals) and the manufacturers. In the last twenty years or so the scale of operations of the raw metal producers, broadly speaking, has increased much more than the scale of operations of the manufacturer. The producers of copper, lead and zinc in particular mostly operate on a large scale and the small producers account for a small proportion of the world output. The small manufacturers, on the other hand, account for a very substantial proportion of the output, particularly in this country and on the Continent. In consequence co-operation between raw metal producers became easier to establish than co-operation between manufacturers, and a stage was reached at which, when trade was depressed, the raw metal producers began to play a leading part in securing an expansion in the consumption of the manufactured materials. As a result both of this and other causes, co-operation between producers and the manufacturers has grown, and it would not be a difficult step further to ensure that the production and distribution of, say, rolled wire rods, wire, sheets and strip and of brass castings, tubes, rods, sheet and strip, etc., were fully co-ordinated with the production and distribution of copper and zinc.

5. I mention this point because it is easier to advocate in general terms the planning of the metal industries than to envisage the organisation necessary to carry out such a policy. There are many who feel that the necessary organisation would be so complicated and unwieldy as to make the work of planning impossible. I do not think that a return to *laissez faire*, which is the only alternative, is possible, but it cannot be overemphasised that planning demands not only an organisation possessed of the fullest information, able to lay down general policy, but also, on the executive side, organisations able to carry through these policies. Planning cannot and should not be concerned with more than the broad outlines of policy; the details must be filled in by the executive organisations, and the planning authority must see that there are executive organisations capable of filling them in.

6. If prices are not to be fixed by the free interplay of supply and demand on a commodity exchange, how are they to be determined? The only alternative is in relation to costs, not costs at the mine or at the smelter but costs delivered to the consuming works. We became accustomed in the pre-war years to thinking in terms of a restrictive economy, a buyers' market in which there was always more to sell than was wanted.

War conditions have changed this outlook, but most people instinctively think that in the post-war period there will be a return to a buyers' market. Neglecting the possibilities of a post-war boom, which it should be one of the first objects of planning to avoid by laying down priorities and planning a programme of reconstruction and development over a period of, say, ten years, it is very doubtful whether we shall have a return to a restrictive economy. Heaven help us if we ever again see two million unemployed here and six million in the U.S.A. and dump our sugar and coffee in the sea. It is much more likely that the emphasis will be on securing the supplies of metals or other commodities and of labour necessary to carry out the reconstruction and development programme laid down. If this is so, it will be a further influence shifting the emphasis away from prices and on to costs—not so much monetary costs except in so far as these provide an index of the use made of labour and materials.

7. The general considerations outlined above lead to one further corollary—that control of international trade must also be envisaged. Whether this takes place through the type of export and import licence machinery at present used or through unification of exporting and importing remains open for further discussion. But control of international trade is bound, among other repercussions, to affect fundamentally the position of the custom smelters. The origin of custom smelters varies fairly widely. In some cases, such as tin, they have depended on highly specialised 'know-how'—a factor which has decreased in importance, as the development of electric smelting in the Belgian Congo and the new Corpus Christi smelter in Texas show. In others a smelter has been erected to eat the output of a mine which has later been worked out and has taken on custom smelting to keep going. In others again there has been financial ownership of or interest in mines in one or more countries by a smelter in another. Some of the ores treated by the American Smelting & Refining Co. and the American Metal Co. are obtained in this way. In many cases custom smelters undoubtedly enable metal to be produced cheaper than could be done by having a smelter serving the mine or a group of mines, but there are examples, e.g. in Belgium, of concentrates coming from one end of the world and metal travelling back again. This is a problem which would have to be tackled by the planning authority.

8. Discussion of planning in relation to the mineral industries must not be confined to the major minerals and metals. Indeed such discussion cannot be confined to the mineral industries. Phosphates must bring in the chemical industry and other branches of the mineral industry in connection with sulphuric acid supplies and also agriculture. Natural nitrates must also bring in the chemical industry and agriculture. Copper, the electrical industry and the whole range of engineering. Tin brings in tinplate and steel. The list of inter-connections can be multiplied indefinitely. The mineral industries are not in a position to plan their own future irrespective of other industries.

9. In conclusion, if planning of the use of the mineral resources of the world is to be undertaken :

(i) There must be a central international planning authority which will lay down the general framework and will correlate the plan for the mineral industries with the requirements of and plans for other industries.

(ii) The necessary executive machinery must be organised. This could probably be built up out of existing bodies inside the mineral industries. Execution must be left to the mineral and metal industries themselves.

(iii) There must be no 'outsiders.' The British and American Governments will have the necessary sanctions to see that there are not. They must be ready to use them.

(iv) Planning of production is meaningless and would be abortive if unaccompanied by planning of distribution and consumption. Markets may have to be divided on the basis of priorities of requirements and economy in transport and distribution. This may involve radical changes on the production side—e.g., in the position of some custom smelters.

(v) The determination of prices by the free interplay of supply and demand on a commodity exchange is incompatible with the planning of production and consumption. If emphasis shifts, as it should, from restriction of output to maintenance or expansion of output to supply all requirements envisaged, prices will play a secondary part. They are likely to be increasingly related to costs. If prices are established, producers and manufacturers will not need to protect themselves against fluctuations.

(vi) International trade is bound to be controlled and possibly unified in exporting and importing organisations for each group of commodities and manufactured goods.

Dr. L. Dudley Stamp

The Exploitation of Minerals in relation to National and World Planning

ALL minerals are won by what used to be called 'robber economy.' Man has no control over the location of minerals : his efforts are directed towards the discovery and subsequent winning of deposits whose position is dependent upon the geological structure of the earth, or towards the utilisation of deposits not previously regarded as 'economic.' Once any given deposit is exhausted it is not replenished.

Thus the social and economic consequences of the extractive industries are entirely different from those which result from industries connected with either the animal or vegetable kingdoms. In those cases, provided adequate care is taken, nature replenishes the stores year by year, and the dependent industries are afforded a marked degree of permanence. By the limited nature of the resources on which they depend, mineral industries, whether merely extraction or processing or secondary industries based thereon, are essentially impermanent.

It is of considerable importance to distinguish between two groups of economic minerals. In the first place there are those which occur in limited supply and where the object of mining is to remove *all*, or as much as is economically feasible, of the mineral. Into this category come

oil, coal, iron ore (at least over a certain metal content) and most metalliferous ores. In the second place there are those minerals which occur in such abundance that only parts of the available deposits are ever likely to be worked. Into this category come limestone (including chalk) for lime and cement, clay for bricks and tiles, slate, building stones, road metal, sand and gravel. In the international planning of mineral exploitation it is the first group which is concerned : the rocks and minerals of the second group are of the greatest importance but nationally rather than internationally. In the minerals of the first group there is little choice in the siting of the works : in the minerals of the second group it is possible to plan the actual areas of working to a considerable extent—they are usually dictated primarily on economic grounds, especially in relation to transport costs, but where necessary may be planned in accordance with requirements of the national planning of the location of industry, the conservation of agricultural land, the preservation of amenities and so on.

Restricting attention to the minerals of the first group, those of which the object is to remove the whole or as much as possible, a definite cycle is associated with the working. This is, briefly, exploration, exploitation and exhaustion. With *exploration* and the early stages of exploitation comes a very rapid development, an influx of population, a spate of building and often of extravagant expenditure—indeed all the conditions associated with a ' mining boom,' whether it be a gold rush, an oil boom, or simply the development of a new coalfield. The period of relatively steady *exploitation* may be short (as in the case of alluvial gold or tin) or it may be long—even running into centuries (as in the case of a coalfield). If it is long, then social and economic conditions become stabilised, substantial towns are built and the whole community may go so far as to forget that its existence is primarily dependent on the exploitation of a mineral deposit. This is the position reached in many of the older coalfields of Britain. The period of *exhaustion* or approaching exhaustion is one of serious and inevitable maladjustments often resulting in much human suffering and misery and which calls for careful thought and action—it cannot be left to right itself.

Thus the recognition of the right of the nations of the world to share the world's mineral resources carries with it the obligation of those nations to accept responsibility and to share the burden of whatever social and economic readjustments may be needed. There is, in other words, an obligation to safeguard the interests of human beings both during and after the exploitation of the minerals.

Most of the problems which arise and some of the readjustments can be illustrated, though on a small scale, in the British Isles :

(*a*) Tin has been won in Cornwall and the south-west since pre-Roman times. Exploitation reached its peak in the seventies and eighties of last century and resulted in a large number of mines with their conspicuous pithead gear widely scattered over the wilder parts of the country. At least two not inconsiderable towns, Camborne and Redruth, grew up dependent primarily on mining. To-day most of the deposits are sufficiently near exhaustion that in pre-war years their exploitation had become uneconomic. As a mine approaches the later stage of its career, there is little money left after running costs have been met and, when the mine fails, none at all to remove the old gear and buildings, which thus become unsightly ruins marring the countryside. In the case of the Cornish tin mines much of the skill, experience and capital released from local mines was transferred abroad—many Malayan companies are offshoots of Cornish parents and are often staffed by Cornish miners. Camborne and Redruth came to depend on foreign investments—one solution, perhaps a rare one, of the problem.

(*b*) Lead was won by the Romans, and at this moment is being worked again, in Cumbria and elsewhere. The position is much as with tin, except that there is here an additional complication—that of noxious effluents and poisonous fumes from smelting. The first promises often to destroy freshwater life, including valuable fisheries, the second may ruin agriculture as well as natural vegetation for miles around. The aftermath is terrible. The same is true of the extraction of salt, gypsum, and the associated heavy chemical industries.

(*c*) Iron ore. The once flourishing iron industry of the Weald has gone, leaving little or no trace ; the iron industry of the South Wales coalfield is more recent and has left behind a solid core, in peace-time conditions at least, of unemployment. In the Black Country the evils have been mitigated by the switch over to other industries. The latest phase of maladjustment in the iron industry is seen in Northamptonshire, where thousands of acres of good agricultural land are being left, after removal of the ore, a stony desert of steep ridges and valleys useless to man and beast and affording little hope even for useful vegetation or afforestation. Yet a limited expenditure, with the aid of modern levelling machinery of the type now being used on aerodromes, *could* restore this land to usefulness.

(*d*) Slate quarries, chalk quarries, and other scattered surface workings, including those for gravel and sand, raise especially questions of amenity and the need for regulation, including definite directions towards the location of industry, in national planning.

(*e*) Coalfields afford examples of the problems raised by mineral working at their most difficult. A coalfield develops slowly and its development gives rise to such permanent towns and villages that the subsequent problems of readjustment are almost unbelievably difficult. So rooted are the human beings that the solution of the problem has tended to be, not the ' scrapping ' of the settlements—which is the logical course—and the removal of the people, but the deliberate effort to bring industry of new types to the pool of labour thus available.

These examples, drawn from Britain, are sufficient to illustrate the far-reaching character of the human and economic problems raised by the apparently simple proposition of sharing the world's mineral resources. It would seem that three principles emerge :

(*a*) Mineral exploitation inevitably results in a

need for *restoration*, whether it be of land or of the social structure of the community.

(*b*) This restoration should be obligatory on those, whether nations or individuals, who derive benefit from the working of the minerals.

(*c*) In the later stages of mineral exploitation there is never a surplus of money, and therefore there should be some provision, comparable to an amortisation insurance, made when the industry is flourishing, for use in those later stages for the work of restoration and rehabilitation.

Discussion

Sir Harry Lindsay expressed his gratitude to the Chairman for the opportunity not only to support the resolution but also to point out that the Imperial Institute would have definite contributions to make to the action which the resolution commended to the Council of the British Association, and particularly towards the preparation of a scientific survey of mineral resources. It might be thought that such a survey would be a comparatively simple matter comprising a tabulation of existing statistics. He held, on the contrary, that a survey of this kind would prove to be a formidable task. Every nation is a law to itself in the compilation of its own mineral statistics, with the result that the statistics themselves are by no means comparable. Nor are only statistics involved. Prof. Boswell, during the First Session, had described the publications of the Imperial Institute as essentially statistical. This, however, was by no means the case, for the Institute was responsible for the compilation, publication and, where necessary and possible, the re-publication in up-to-date form of some fifty monographs, each of which gives a comprehensive digest of information about the resources, trade and industrial utilisation of a single mineral. The Imperial Institute had had forty years' experience of work of this character which required a synthesis of the knowledge and experience of geologists, mineral technologists, statisticians and last, but by no means least, experts in foreign technical literature. The Mineral Resources Department of the Institute had been very carefully organised with a view to comprising this knowledge and experience, and he could claim that the staff of the Department were fully competent to prepare a survey of mineral resources not only of the British Empire but also of foreign countries. Some special support would be necessary to fit a work of this magnitude into the existing work of the Institute, but he did not despair of the necessary support being secured.

Resolution

At the conclusion of the Conference, the following resolution was proposed by the President of the Association, Sir Richard Gregory, Bart., F.R.S., seconded by Dr. C. H. Desch, F.R.S., and carried unanimously.

That this Conference on Mineral Resources and the Atlantic Charter, convened by the British Association's Division for the Social and International Relations of Science, requests the Council of the Association to consider means by which the Association could assist in the carrying out of the Fourth Article of the Atlantic Charter, which postulates access for all States on equal terms to the raw materials of the world.

This Conference, having specifically dealt with mineral resources, submits that, as a first step, the Council should initiate forthwith consultations with appropriate scientific and technical organisations, to secure an understanding on the principles involved. The Conference would further urge that a scientific review of mineral resources, using and supplementing all existing data, should be among the first tasks of any international organisation for the social applications of science, such as was envisaged at the recent Conference on Science and World Order. To this end, the Conference recommends that the Council should consider how it might help to promote the establishment of an International Resources Organisation, as a fact-finding and advisory body for Governments, as a contribution to world stability, and in the spirit of the Atlantic Charter.

MINERAL RESOURCES AND THE IMPERIAL INSTITUTE

By Sir Harry Lindsay, K.C.I.E., C.B.E., Director of the Institute

(Communicated, August 1942)

In the course of the recent Conference upon Mineral Resources and the Atlantic Charter a number of speakers, both in presenting their papers and in contributing to the discussions, made reference to the work of the Mineral Resources Department of the Imperial Institute, and I was naturally gratified to hear each one of them express his appreciation of the results that this small group of workers (and it has always been a very small group) has been able to achieve despite its chequered and often precarious existence.

I am fully aware, however, that the work has not received the recognition it deserves and that its scope is by no means so well known as it should be. Indeed, one or two of the speakers at this Conference gave the impression that they believe the function of the Department to be mainly the collection and publication of statistics of the mineral industry, whereas in fact the statistical part of the work is but one and by no means its chief function. Let me then try to summarise briefly the history and objects of the Mineral Resources Department in order to bring out its bearing upon the problems faced at the Conference and to indicate the resources of knowledge, information and experience which are available at the Institute and ready to be placed at the disposal of those whose duty it may be to implement the objects adumbrated in the final resolution passed by the Conference.

In the original Charter of Incorporation granted to the Imperial Institute in 1888 it was provided that one of its purposes was ' the collection and dissemination of such information relating to

trades and industries . . . as may be of use to the Subjects of our Empire,' and in compliance with this it was decided to issue a publication dealing with ' the physical geography, the natural resources, and the industries and commerce of the Colonies and India, and embracing facts and numerical data relating to these and other important heads which have hitherto not been dealt with in a comprehensive manner in one publication.' Thus began our long series of publications, the first of which was an Imperial Institute Year Book which appeared in 1892 and contained notes on the mineral industries of all the constituent parts of the Empire. In 1895 the Year Book became a Journal, and in 1903 the publication of the quarterly Bulletin of the Imperial Institute commenced ; I am happy to say that it has continued ever since. Since its inception every volume has contained notes, articles, reports or statistics on some aspect or other of the mineral resources or mineral industry of the Empire.

For a good many years, too, the Institute has been actively engaged in investigating the nature and extent of the mineral resources of the Empire and in ascertaining the suitability of minerals from Empire sources for industrial purposes. Among the earliest of our scientific reports, for example, was a series concerned with the results of work done in our laboratories upon the coals of India, which at that time, in the last century, were practically undeveloped. This practical work was carried further when in the early 1900's a number of Mineral Surveys were carried out under the supervision of the Institute, when geologists were selected and sent out to Ceylon, Nigeria, British East Africa and elsewhere. This pioneer work achieved results of considerable value—for instance, the finding of the Udi coal-field—and laid the foundation for the subsequent Colonial Geological Surveys.

I think one may say that this country began suddenly to appreciate the importance of a study of Empire mineral resources when during the last war our sources of normal supply of many raw materials were either cut off or seriously endangered. The Institute then commenced to publish a series of monographs on specific economic minerals. To meet the urgent needs of the time, also, an independent body—the Imperial Mineral Resources Bureau—was formed with a much larger staff of compilers, which also undertook the publication of economic mineral monographs. With the coming of peace, however, the new body failed to receive adequate support and in 1926 it was merged with the Mineral Section of the Institute. Its mineral publications and those of the Institute were amalgamated, and we now have a series of mineral monographs numbering fifty or so, each devoted to a particular metal or mineral or to a related group of minerals. Our aim before the present war was to achieve a quinquennial revision of the whole series, but we have never yet had the staff to achieve this object.

There is also, of course, our well-known Statistical Summary in which we endeavour to collect together annually the published statistics of production, imports and trade in minerals throughout the world for the preceding triennial period. That it does not provide as complete a picture of the mineral industry as many people desire is largely due to the very incomplete data available in many countries and to the heterogeneous nature of these data. But the compilation of mineral statistics is a pursuit which bristles with difficulties, and this is not the place for me to enter into a discussion of them.

Among other publications of the Mineral Resources Department too I must mention a series on the Mining Laws of the Empire, a volume on Mining Rents and Royalties, and, perhaps most apposite of all in relation to the work of the Conference, a Survey of the Mineral Position of the British Empire (1937).

Apart from publications, the Department examines and reports on specimens and samples sent with a view to ascertaining their possible utility or actual commercial value. It also performs the function of a technical information bureau on almost every conceivable aspect of the mineral industry. All these activities, however, I have described in a recent paper to the Institution of Mining and Metallurgy (*Bull. Inst. Min. Metall.* 1942, Nos. 449–451). But at present, of course, its normal functions are curtailed and its resources of information both technical and commercial have been put at the service of the new Ministries and Service Departments ; and they have not been backward in making use of them. In such a manner, in accordance with the terms of the Imperial Institute Act, 1925, we are enabled to advise on the development of Empire resources of raw materials for the purposes of *Imperial Defence*, as well as for use in commerce and industry.

The holding of the British Association Conference marks a re-awakening of interest in this country in the study of the distribution and uses of economic minerals. It is a specialised branch of the study of the distribution of the raw materials of industry, and one which presents problems quite different from those connected with other raw materials. Sir Thomas Holland has drawn attention to the ' speed of change in the international bearing of mineral questions which gives them special urgency,' to the speed of consumption of materials which cannot be replaced, and to the general failure to realise the dependence of progress in civilisation upon the international exchange of minerals. Let us hope then that this re-awakened interest will not again be allowed to die as it was so soon after the last international struggle. No nation is self-sufficient in economic minerals but the United Nations between them are practically so, and if they can co-operate in times of peace on the lines laid down in the Atlantic Charter, and only if they can do so, the steady progress of civilisation will be able to evolve.

My object in contributing this brief account of the work of the Mineral Resources Department is to emphasise my view that in it is to be found a nucleus of experience and information which could well be made the foundation stone of that organisation which will inevitably have to be built for the purpose of wisely developing and controlling the distribution of the vast resources of minerals that lie in the territories which owe allegiance to the British Crown.

POST-WAR UNIVERSITY EDUCATION

Interim Report

University education after the war, and the rehabilitation of universities destroyed or injured during the war, were among the important questions raised at the Conference on Science and World Order, held in September 1941, by the Division for the Social and International Relations of Science.

A Committee was subsequently appointed to consider and report upon these matters. It consists of Dr. J. C. Maxwell Garnett, C.B.E. (Chairman) ; Prof. F. E. Weiss, F.R.S., and Mr. A. Gray Jones (Joint Hon. Secretaries) ; Prof. J. D. Bernal, F.R.S. ; Mr. W. B. Brander, C.I.E., C.B.E. ; Mr. A. M. Carr Saunders ; Prof. René Cassin ; Dr. Jaroslav Cisar ; Prof. W. E. Le Gros Clark, F.R.S. ; Mr. Willard Connely ; Prof. A. C. G. Egerton, Sec. R.S. ; Dr. A. P. M. Fleming, C.B.E. ; Mr. C. W. Judd ; Prof. J. L. Myres, F.B.A. ; Dr. A. D. K. Owen ; Dr. R. Priestley ; Mr. Dennis Routh ; Dr. H. M. Sinclair ; Prof. J. G. Smith ; Dr. C. H. Waddington ; Sir Alfred Zimmern ; together with the President and General Officers of the British Association, and the following members of the Executive Sub-committee of the Division for the Social and International Relations of Science : Mr. Ritchie Calder ; Mr. E. Carter ; Dr. C. H. Desch, F.R.S. ; Prof. P. Sargant Florence ; Prof. A. V. Hill, Sec. R.S. ; Dr. J. S. Huxley, F.R.S.

The terms of reference to the Committee are embodied in the following Interim Report on university education in the post-war world. The report was presented by the Committee to the Council in September 1942.

I. The first of the Committee's three terms of reference is : ' To consider the general policy and methods of university education with a view to promoting international collaboration and the free interchange of ideas, and relating university education to the needs and service of the community.'

The Committee make the following recommendations under this head :—

Age of Entry

(1) Entry to universities should as a rule be deferred until after a year of approved national or international service, whether civil or military.

Some attempt should be made to relate such service to the intended professions of students of applied science. Engineers, for example, might do a year of workshop training in industry ; medical students might be given the option of spending some part of their nineteenth year in hospitals or in other kinds of welfare work ; and students of agriculture might work on farms during the summer months of their service year.

A year's education abroad after the age of eighteen might be accepted as one form of international service.

This proposal would make the ' modal ' age of entry into universities not less than 19. Such a change would benefit the community as a whole, the universities, and the students who would bring to their academic studies and to their social intercourse greater maturity of mind and more experience of life.

Entrance Tests

(2) Academic tests of fitness to enter a university should consist of two parts. The first should be a test of general education and the second of special knowledge. An ever-widening group of universities, including from the outset all those in the United Kingdom, should accept each other's tests of general education, so that a candidate who is qualified in this respect to enter a university in his own country or province will not have to submit to another general examination in order to enter any other university within the group. Each department of each university should satisfy itself that a candidate's special knowledge is sufficient for the work he wishes to do in that department.

The advantage of this proposed reform would not be seriously impaired if certain universities were to insist upon every candidate for matriculation possessing, as part of a general education, some one particular kind of knowledge—for instance, of Latin or of Greek—not required by other universities in the group. To compel a candidate, whose general knowledge was otherwise satisfactory, to take one paper in a single subject would be far less objectionable than the present practice. But the Committee would prefer that the adoption of their recommendation should be subject to no such exception. In that case, Latin or Greek could still form part of the special knowledge required of candidates desiring to study in any particular school of any university in the group.

Entrance Scholarships

(3) The award of entrance scholarships should depend, more than at present, upon a candidate's character (particularly his purposefulness, enterprise, initiative and originality) as well as upon his knowledge and intellectual qualities. To this end the electors to such scholarships should—pending further investigation concerning suitable tests for qualities of

character—have before them a record of each candidate's previous work and other activities, and every candidate should be interviewed before being offered a scholarship.

The adoption of this proposal would increase equality of opportunity for candidates of equal ability and equal promise. It would also encourage schools to provide a more all-round training, and particularly more social training, by means of out-of-school activities.

Residence

(4) At least one year's residence in college or in a university hostel should be required of every internal candidate for a first degree.

The Committee had figures placed before them showing that the cost of making this change (without so adding to the expense of a university education as to exclude any student however poor) would be far from prohibitive. The Committee are making further inquiries into the question of costs.

Tutorial Superintendence

(5) Universities in which a system of tutorial superintendence is not at present in being should work towards such a system as will ensure the personal direction and oversight of every undergraduate's studies.

It is through the informal teaching, supervision and direction provided by a complete tutorial system that the all-round development of the undergraduate can be most effectively secured and the impact upon him of the university environment most readily intensified. That would be especially true for non-residential universities where, largely owing to financial limitations, the tutorial system is to-day least developed.

Freedom to Discuss

(6) Freedom of thought and expression is indispensable in every university. It has long been the tradition of universities in Europe and America. In particular it should be assured to undergraduates discussing world affairs.

International Communication

(7) Apart altogether from the academic study of language and literature, every university should require its students to be able to make themselves understood, by speech and writing, in some one auxiliary means of international communication.

This is not a question of learning another language but of devoting one long vacation to the acquisition of an auxiliary means of communication. Basic English, for instance, has only 850 words, whereas the English language contains 240,000, while French has 100,000 and Italian 80,000 words. A sufficient acquaintance with Basic English could be obtained in a few days by the very many post-war students who will be able to talk English. Some such means of communication is needed in the interests of 'international communication and the free interchange of ideas.' Professional diplomats can, of course, transact their business in a common language. Since it ceased to be Latin it has generally been French and is likely, in future, to be English. English is one of the two languages of the Anglo-Soviet treaty and the common language of Generalissimo Chiang Kai-shek and the peoples of India. The last century saw a steady increase in the number of international conferences where the delegates represented not Governments or Foreign Offices, but unofficial bodies of persons interested in some aspect of science, art, law, industry, commerce, human welfare or social justice. Such unofficial conferences are likely to be more frequent after the war. Skilled interpreters enable all the delegates to grasp what is going on in the actual conference chamber. But, when the delegates meet each other socially, they may not be able to understand each other; and yet their informal talks might do more than set speeches to promote the success of their conference as well as 'international co-operation and a free interchange of ideas.'

The desirability of promoting the introduction of an auxiliary language as an international means of communication was given particular attention after the World War of 1914–18, and the position and prospects of this subject were surveyed in a report of a British Association Committee published in 1921. In order to present the problem in a comprehensive manner, the Committee communicated with leading authorities and associations having special knowledge of classical and modern languages as well as interest in the use of an international auxiliary language. The particular claims of three types of such a language were stated, namely :

(i) A dead language, e.g., Latin.
(ii) A national language, e.g., English.
(iii) An invented or artificial language, e.g. Esperanto and Ido.

The advantages and disadvantages of each of these types were considered by the Committee, and as the result of this analysis, the following conclusions were reached :—

(i) Latin is too difficult to serve as an international auxiliary language.
(ii) The adoption of any modern national language would confer undue advantages and excite jealousy.
(iii) Therefore an invented language is best. Esperanto and Ido are suitable; but the Committee is not prepared to decide between them.

Since the publication of the British Association's report twenty-one years ago, the great political changes which have taken place—or which will have taken place when the United Nations have emerged victorious from the present struggle—point to the fact that any auxiliary means of communication will have to be closely related to the English language and to be such that the learning of it is a direct step towards learning English. The Universities Bureau of the British Empire, and the new Association of University Professors

and Lecturers of Allied Countries in Great Britain, could very appropriately assist in promoting the movement for an auxiliary means of international communication by preparing a report on the question whether Basic English is suitable for the purpose, and, if not, what alternative is to be preferred.

Graduate Scholarships

(8) Graduate scholarships, sufficient to cover passage money and all other necessary expenses, should aid the exchange of students between the universities of different countries.

A one-way traffic is not enough. For example: many more American graduates would in the past have fulfilled their desire to come to British universities, if these British universities had been able, as many American universities were, to provide free board, lodging and tuition, and if, moreover, these British universities had been able more often to provide their outgoing graduates with free passages to America. Perhaps the British Council will help to provide a remedy in this instance; or, alternatively, some of the expenses might be provided in the manner proposed in the next recommendation.

An International Education Organisation

(9) In order that the different countries may pool their experience of university and other education, there should be created as one of the organs of any post-war Society of States (or other international authority) an International Education Organisation representative of teachers (including university teachers), governing bodies, local education authorities, and governments. This body should make inquiries, offer suggestions, issue reports, encourage experiments and give, where needed, grants in aid of education in its international aspects.

Adult Education

(10) The special responsibilities of the universities in the sphere of non-vocational adult education, as well as for some other purposes of higher education, should be recognised, and the universities should be associated with this work.

* * * *

In a subsequent report the Committee will have further recommendations to make on matters covered by their first and second terms of reference. Among these matters are:—

(*a*) conditions for the award of scholarships and maintenance allowances for undergraduates (whether awarded by universities or colleges, by the State, by local education authorities, or by other bodies);
(*b*) university finance;
(*c*) universities and the training of teachers;
(*d*) provision of science for non-scientists;
(*e*) universities and government administration (graduate schools for future or existing civil service, combining university work with practical experience in government offices);
(*f*) the training of an international civil service.

II. The Committee's second term of reference is: 'To consider the replanning of teaching departments and curricula in accordance with modern conceptions of the interrelation of different branches of knowledge, particularly those of science and the humanities.'

In considering this matter the Committee have been impressed by the tendency of university studies to split up into a growing number of separate specialisms more remarkable for their diversity than for any integrating principle other than 'simultaneity and juxtaposition.' Little is done to ensure that every undergraduate is faced by the need for working out a philosophy of life. Moreover, the separate specialisms tend to be increasingly divorced from the life of the community.

Two distinct proposals have been submitted to the Committee. The first (A) is for a type of general degree course including both natural science and humanities. The second (B) is for including in the existing specialised schools in Natural Science and Applied Science courses in the elements of sociology and citizenship.

A

As a first step towards the reintegration of the university work of an increasing proportion of undergraduates, and at the same time clearing the universities of the charge of neglecting the non-vocational education of citizens while concentrating upon the vocational training of specialists, the Committee would welcome the institution of honours and pass schools of 'Philosophy, Natural and Social.'

These schools would seek to provide an outlook on the modern world seen as an integrated whole against a background of natural science. While, however, the course of study would include both the physical environment and the human environment (the natural sciences and the social sciences), the ultimate aim would be 'to construct a system of ideas which bring the æsthetic, moral and religious interests into relation with those concepts of the world which have their origin in natural science.'

These words are quoted from Prof. Whitehead, who goes on to say: 'Philosophy frees itself from the taint of ineffectiveness by its close relations with religion and with science, natural and sociological. It attains its chief importance by fusing the two, namely religion and science, into one rational scheme of thought. Religion should connect the general rationality of philosophy with the emotions and purposes springing out of existence in a particular society, in a particular epoch, and conditioned by particular antecedents' (*Process and Reality*, 1929, pp. vi and 21).

Even if no final integration is possible without going into the realm of hypothesis, that is, after all, the way of discovery which has led to the substantial achievements of natural science.

The study of natural science in such a course must be wider than any of the specialist science schools : e.g., chemistry and physics should be taken together as part of ' physical science,' and general biology in place of the separate treatment of zoology, botany and physiology. It would not be possible to cover the whole subject matter of any major science. But such detailed knowledge is less important for the present purpose than a sound apprehension of scientific method. It is, however, essential that, within a selected group of topics, there should be opportunity for observational work in the field and for practice in experimental work, preparation and analysis of chemical substances, use of electrical instruments, and the like.

Along with an outline of the physical world as conceived by the exact sciences, the first two years of the course would include the history of discovery, whether in natural science or scholarship, studied in relation to social and political history, particularly of the periods of the greatest advances in scientific thought. The study of man and society, including the contemporary international community, should be begun in the first year and would extend throughout the second year.

In English universities the first two years' course might cover :

A. Physical science, including astronomy, with emphasis on the order in which the several facts have become known. Many students would not need to continue the study of this subject beyond their first year.

B. Biological and geological science : the elements of animal and plant evolution, development and function.

C. History of science and learning, with references to political and social history.

D. The social sciences, including sociology, anthropology and psychology, with the elements of moral and political philosophy.

Candidates would be examined in these four subjects at the end of their second year. Candidates for an honours degree would be asked to translate and comment upon passages from French and German authors, including set books.

The last year would link together all the previous work, whether in natural science or the humanities, and bring it into relation with the best philosophic thought of the western world, begun by Plato and Aristotle and continued by the greatest modern thinkers from Descartes to Whitehead. For the purpose of the present proposals, the chief problem of philosophy is not so much to explore ultimate reality as to construct in men's minds a working model that fits all kinds of human experience, not only of space and time but also of æsthetics, morals and religion. This implies some study of psychology as an experimental science.

The success of such courses in ' Philosophy, Natural and Social,' will depend upon the tutors or directors of studies. Makeshift arrangements may be inevitable at the start of some of the new schools. But little good can come of setting undergraduates to study natural science, sociology, and philosophy under the direction of different tutors for different groups of subjects. Indeed, it would be fatal if the universities were to encourage undergraduates to read ' Philosophy, Natural and Social,' without the continuous guidance of a staff of tutors in whose minds the whole course had already taken shape as an organised unity. The difficulty of finding men willing and able to fit themselves for this task will be diminished when the war is over, because the war work of many of the younger university teachers will have widened their experience of public affairs and deepened their interest in the question how the universities may best help to educate some of the leading citizens of the post-war world.

The above recommendations, in part II (A) of this *Interim Report*, are partly derived from proposals for an Honours School of Philosophy and Natural Science which were considered in 1923 by the University of Oxford, and which have recently been informally revived.

B

The Committee have also considered, and they approve, the following proposals for introducing some study of sociology and citizenship into specialised Honours Schools in Natural Science, Applied Science and Technology.

Section 1

The tendency of university studies to split up into a growing number of separate specialisms has already been noted by the Committee. They have recommended schools of Philosophy, Natural and Social, to meet ' the charge of neglecting the non-vocational education of citizens.' But it must be realised that the interrelation of science and the humanities in university teaching is important also for the students preparing for a professional vocation in science. Typically, such a student at present devotes his whole time to science, pure or applied. He has usually little knowledge of world affairs, or of the government even of his own country and locality. If he lives at home, as the majority of students do in most of the modern universities, his entire university life may, and often will, consist in attendance at science lectures and laboratories, with a break for lunch in the refectory. The rest of his ' student ' life is spent at home, where he may not find any stimulating discussion. Foreign scientists, scholars and students residing in the United Kingdom have been astonished that the future leaders of this democratic country should know so little about the workings of democracy or its achievement in social welfare.

This ignorance is particularly marked in students of the applied sciences such as engineering, chemistry or medicine, and it is suggested that, at least in their first year or two, students in Science Faculties should attend some discussion classes in subjects outside their specialism.

Section 2

It would probably be a mistake to compel attendance at courses of lectures in Arts or Commerce Faculties. Science students should be addressed by persons who understand their background interest. If possible the proposed classes

should be integrated with the students' specialism. Thus medical students could be introduced to social problems by a course on public health, the administration of public health services, vital statistics and human needs. Engineering and chemical students could find interest in a course on industrial history, industrial welfare and the organisation of engineering and chemical factories, including relations with Trade Unions and the machinery for collective bargaining that is so characteristic of British democracy.

These 'special interest' courses would undoubtedly be of direct help to students in their future professions; and, though few universities have adopted them, there should not be too great a difficulty persuading Faculties of Science to agree to them.

More difficult will be the provision of *courses and discussion groups of a more general nature* on citizenship, social and industrial relations, anthropology, psychology or other branches of humanities. If the special interest courses are given in the first year, the general courses might follow naturally in the second year (as they do in the Massachusetts Institute of Technology), and should, again, be given by persons understanding the background interests of science students. Though the course should be compulsory, alternative options should be provided. It is to be hoped that once he started to think about social affairs in his first two years, the science student would continue in later academic years under his own steam and would take full advantage of debating and political societies organised by students themselves in their union or guilds. This consummation would be helped if the university courses suggested for the first two years aroused interest and stimulated discussion, reading and observation, rather than being regarded as an end in themselves.

Section 3

This provision of a new type of education for scientific workers is inseparable from provision of a new basis of instruction for government and administration. The core of the problem is this: how can we build a bridge between the teaching of natural science (including medicine and engineering) on the one hand and the teaching of humanities (including economics) on the other?

So far as British universities are concerned, we have to start by frankly recognising that their present teachers are the product of a system which sharply divides training in technics on the one hand from the study of industrial, social and political organisation on the other. Very few scientific workers have much insight into social problems. Very few historians, economists or linguists have even a passing familiarity with the elements of natural science and its technical possibilities, or with scientific method in general.

It is because too few men of science as yet have this insight and too few humanists have such knowledge, that it would be a mistake to make attendance at courses in arts and commerce compulsory for students of natural science (or courses in natural science compulsory for students of commerce and arts).

For this reason we cannot force the pace. The direction in which we are moving is important; but the speed at which we move is limited by the materials to hand. We have to create the teachers who have the equipment to transform the existing educational system before we can produce far-reaching changes.

Inter alia, there are two ways in which we can catalyse the change by creating new teachers with a new outlook:

(*a*) by developing the teaching of general science as a universal ingredient of the school curriculum;

(*b*) by encouraging provision of courses and creation of departments for borderline subjects in the universities.

The teaching of general science in schools entails re-orientation of school science teaching with more emphasis on its civic implications. This will be possible only in so far as we provide instruction for teachers on the social background and the social foreground of science. A step in the right direction would be to introduce readerships, or other senior posts, in the social history of science in departments of education, and to scrutinise appointments of heads of educational departments with a view to appointing individuals who have made the social history of science a speciality. In this context social history does not mean social biography. It implies the historical study of scientific progress *vis à vis* the interplay of technics and human needs.

Borderline disciplines include social medicine and vital statistics in the faculties of medicine and science; social technology (as initiated at Wisconsin), and demography and standards of human needs in the faculties of arts and commerce.

III. The third of the Committee's terms of reference is: 'To survey the position regarding teaching material, apparatus, books and staff in universities which have been damaged, destroyed, disorganised or closed as a result of war, and to make recommendations for their rehabilitation.'

The Committee recommend:

(1) That the United Nations should, as part of their Armistice terms, require the enemy Powers to make full restoration of university property stolen or destroyed in the countries they have occupied;[1]

(2) Seeing that many scientific instruments and much apparatus now in use for war purposes will be of great value for university teaching and research when the war is over, the Governments of the United Nations should agree in principle: (*a*) that each of them will lend or give such instruments and apparatus to the universities, and particularly to the rehabilitated universities, after the war, and (*b*) that

[1] It has been suggested that some such words as the following be added here: 'and suitable sanctions should continue in force until this restoration is complete.'

they will require similar action of the enemy Powers in the Armistice terms.

The Committee are considering further recommendations under this head. They have obtained from the London International Assembly a substantial amount of information supplied by Allied Governments concerning the damage so far done to universities, their teaching material and their personnel. And with a view to the rehabilitation of universities which have suffered, or may yet suffer, as a result of the war, the Committee have instituted inquiries or taken action as follows :—

(*a*) A list of up-to-date text-books, as well as of standard works and reference books is being compiled for each group of subjects. When these lists are sufficiently complete, the Committee propose to send them to British universities and university colleges, and to the American University Union, with a request that spare copies of the listed books may be collected and retained by the university or college authorities until the Committee ask for them.[1] We recommend that the British Council be invited to help the Committee to buy new or secondhand copies of listed books which may be needed in addition to those obtained as free gifts. The Committee hope that many of the publishers of listed books will sell them at reduced prices for use in rehabilitated universities.

(*b*) Scientific and other learned societies in the United Kingdom are being asked whether they are printing and storing copies of their journals so that universities and libraries abroad may have them when the war is over. Where this is not done, the Committee hope that microfilms of the journals may be made for the use of universities which would not otherwise be able to obtain copies. The Committee have been informed that several hundred microfilm cameras are being used by banks and business houses in England, and that many of these cameras are likely to be available after the war.

(*c*) The Committee are in communication with the British Council and other bodies on the question how many of the university teachers and other scientific workers who have come to the United Kingdom from Allied countries hope to return to the universities of those countries when the war is over. The Committee's help will probably be needed to send other teachers and research workers to those universities after the war. In the opinion of some members of the Committee, who are citizens of Allied States in Europe, it will be necessary for British and American universities to train teachers and researchers for some of the universities whose staff has been killed or dispersed by the Nazis.

[1] But books for Polish universities are to be sent to St. Andrew's University instead of to the Committee.

REPORT OF THE COUNCIL TO THE GENERAL COMMITTEE FOR THE YEAR 1941–42

(SEPT. 2, 1942)

OBITUARY.

THE Council have to deplore the loss by death of the following office-bearers and supporters :—

Lt.-Comm. L. C. Bernacchi
Dr. J. Bonar
Prof. H. L. Bowman
Sir William Bragg, O.M., K.B.E., F.R.S.
Dr. G. C. Cossar
Mr. James Downs, J.P., O.B.E.
Dr. F. A. Duffield
Sir Daniel Hall, K.C.B., F.R.S.
Prof. W. H. Heaton
Mr. C. Oldham
Miss E. I. Page
Prof. W. H. Young, F.R.S.

REPRESENTATION.

The Association was represented at the memorial service for Sir William Bragg in Westminster Abbey by Sir Richard Gregory, Bt., F.R.S., President, and Prof. Allan Ferguson, General Secretary, and at the memorial service in Cambridge by Prof. F. T. Brooks, F.R.S., General Secretary.

Prof. A. H. Reginald Buller was appointed to represent the Association at the 75th anniversary of the Torrey Botanical Club, New York.

Sir John Orr, D.S.O., F.R.S., has been appointed to represent the Association on the Educational Advisory Committee of the Central Council for Health Education.

Dr. O. J. R. Howarth has been appointed as observer, on behalf of the Association, at meetings of the Committee for the Industrial and Scientific Provision of Housing.

COMMUNICATIONS WITH ALLIED INSTITUTIONS.

The President and General Officers forwarded, on behalf of the Association, a message to the Biology Department of the Soviet Academy of Sciences, on the occasion of the exhibition opened by the Department on ' Darwin and the struggle for his theory,' to commemorate the sixtieth anniversary of his death.

The President and General Officers took advantage of Dr. Joseph Needham's mission to China to forward a message to Academia Sinica.

A message was received through Prof. E. D. Adrian, F.R.S., from the Argentine Health Committee to aid Democratic Countries, and a reply was forwarded on behalf of the Association.

The All Union Society for Cultural Relations with Foreign Countries, communicating through the Soviet Embassy, stated that they would be happy to send in exchange any copies of publications of corresponding scientific societies and research institutions in the U.S.S.R., which might be of interest to members of the Association, and that they would welcome the exchange of personal letters between members of the Association and scientists in the Soviet Union. The Council received this statement with satisfaction, and are

glad to call it to the attention of members of the General Committee and others.

The Association was invited to send a representative to the meeting of the Indian Science Congress Association at Lucknow in January, 1943. In view of the difficulty of appointing a representative in present circumstances, a message was sent on behalf of the Council.

Division for the Social and International Relations of Science.

As recently stated in *The Advancement of Science*, the simple mechanism of the Division, in contrast with the elaborate organisation involved in peacetime meetings of the Association, has enabled the Association to maintain activities appropriate to present conditions. Conferences have been held on 'European Agriculture: Scientific Problems in Post-war Reconstruction,' the transactions of which were reported in *The Advancement of Science*, No. 6, and on 'Mineral Resources and the Atlantic Charter,' the transactions of which will appear in *The Advancement of Science*, No. 7.

It is intended to arrange, early in 1943, a Conference on improving the public understanding of the benefits of science.

Divisional Committees have been appointed as follows:—

(*a*) On Post-war University Education (Chairman: Dr. J. C. Maxwell Garnett, C.B.E.). The Council have authorised the publication of an interim report by this committee.

(*b*) On Post-war European Agriculture (Chairman: Sir John J. Russell, F.R.S.). This committee is designed to advise appropriate government authorities on scientific questions as requested, and has already begun to do so.

(*c*) On Science in relation to Land Planning (Chairman: Dr. Dudley Stamp). This committee also is designed to advise government authorities on scientific questions.

(*d*) To consider how the results of scientific research on human institutions and human needs and their inter-relations can best be co-ordinated and brought to bear on the formation of public policy (Chairman: Prof. P. Sargant Florence).

(*e*) A committee is in process of formation to inquire into and report upon the state of knowledge of mineral resources, other than coal and petroleum, essential for modern industrial development, from the point of view of the fourth clause of the Atlantic Charter.

Preliminary consideration has been given to the question of possible international action in relation to scientific terminology.

The above activities and others which continue to occupy the executive of the Association have all arisen out of the Conference on 'Science and World Order,' held in September, 1941, and the subsequent conferences already mentioned.

The Council welcomed the intention of the British Council to make a Spanish translation of the Association's Report on Science and World Order, for distribution in South America.

In addition to the publication of transactions in *The Advancement of Science*, bulletins of proceedings have been circulated to numerous institutions and individuals interested, in order that information may be available as to the activities of the Division in relation to post-war problems and the avoidance, as far as possible, of unnecessarily duplicating the work of other organisations.

General Officers, Secretary, and Council.

The General Officers are nominated by the Council for reappointment:—

General Treasurer, Prof. P. G. H. Boswell, F.R.S.
General Secretaries, Prof. F. T. Brooks, F.R.S., Prof. Allan Ferguson.

Secretary.—Arrangements have been made with Dr. O. J. R. Howarth as to his pension; but in present circumstances the Council do not contemplate his retirement at the previously agreed age of 65, which he will reach in November, 1942.

Council.—It is recommended that advantage be again taken of the Lord President's licence to modify in certain particulars action prescribed by the Statutes, and that no change be made in the personnel of the Council.

The Council conveyed to Sir Richard Allen, C.B.E., their congratulations on his receiving the honour of knighthood.

Finance.

The Council have gratefully acknowledged a grant of £200 from a fund under the administration of the Royal Society towards the cost of publication.

The General Treasurer's Account for the financial year 1941–42 has been audited, and is presented to the General Committee. Grants have been made to Research Committees in accordance with the schedule appended to the Account.

The General Treasurer has placed to the credit of a rehabilitation fund for Down House and the offices of the Association after the war a balance of £445 5*s.* 10*d.* remaining from the Spencer Bequest at November 30, 1941, at which date, under the terms of the bequest, the fund was to be completely expended.

Grants to Research Committees, 1942–43.

The following grants have been approved.

Committee.	*Grant.* £	*Fund charged.*
Seismological Investigations	100	Caird Fund
Mathematical Tables .	25	Math. Tables Fund
Mathematical Tables (printing)	190	Caird Fund
Plymouth Laboratory .	50	,, ,,
Zoological Record . .	50	,, ,,
Insular Faunas . .	10	,, ,,
Bird Behaviour . .	40	,, ,,
Freshwater Biological Station, Windermere . .	75	,, ,,
Algae and Protozoa . .	25	,, ,,
Kent's Cavern . . .	5	Hobson Fund
Post-war University Education	20	Caird Fund

A maintenance grant of £30 has been made from the Leicester and Leicestershire Fund to Mr. J. L. Crammer, Wyggeston School and Christ's College, Cambridge.

Down House.

The thanks of the Council are due to the Trustees of Charles Darwin's MSS. and other papers, and to the Pilgrim Trustees, for their gift of the note-books and diaries kept by Darwin during the voyage of the *Beagle*, certain note-books relating to Down House and the neighbourhood, and other relevant and valuable papers. These will be placed in safe custody pending the re-opening of the house to the public when peace is restored. There have also to be gratefully acknowledged the gift of certain of Darwin's books, finely bound, from Miss Kitson, and of a portrait in oils of Dr. Erasmus Darwin from Mr. Hesketh Pearson.

In spite of further reduction of staff it has been endeavoured, so far with success, to maintain the productivity of the kitchen-garden and other grounds to the full for the use, not only of the resident households, but also of others. Although the house is not open to the public, certain portions of the premises are serving purposes essential to the war effort.

The precipitation for the year 1941 read from the standard rain-gauge was 30·24 in., the average for the five years 1937–41 being 33·47 in.

The attention of readers who are not already members of the Association or subscribers to *The Advancement of Science*, is invited to the review and summary of contents of this journal on pages 279–280, and to the short statement on the work of the Association which appears on p. xiii of the advertisements following the text.

GENERAL TREASURER'S STATEMENT AND ACCOUNT, 1941–42

Balance Sheet.—The endowment assurance policy taken out in the name of Dr. Howarth has fallen in. Until he retires, the Association will hold the capital sum of £2,000 in trust for him.

It will also be noted that the Contingency Fund is slightly reduced as a result of the loss of £3 12*s.* 7*d.* on the year's working (shown in the General Income and Expenditure Account, p. 269), but that we have not yet had to draw upon the Grants Equalization Fund. The number of applicants for grants has inevitably fallen, but none has been refused, for they all appeared to be worthy. We may justifiably feel some satisfaction in having helped to keep the research flag flying under war conditions.

General Income and Expenditure Account.—As a result of the war-service of members of staff, the salaries and wages item was much less in 1941–2 than the ' normal ' figure in 1939–40 : it is only a little higher than in 1940–1, but, looking forward, we should remember that the appointment of an additional temporary assistant has become necessary—especially on account of the activities of the Division for the Social and International Relations of Science—the cost of which will increase the figure for the present year, 1942–3.

Pension contributions are down because we are no longer contributing to the premium for Dr. Howarth's policy.

Printing and binding are up, because of the publication of the *Advancement of Science*, reporting the Division's activities. Here, we must once again acknowledge with gratitude the donation from the A.A.A.S. towards the expenses of the Division. For the current year (and not shown, of course, in this account), we are grateful to the Royal Society for a grant of £200 from the special Rockefeller Grant, towards expenses of publication.

War Damage Insurance on property at Burlington House amounts to £18 3*s.* 9*d.*, and that on contents of Down House £67 10*s.* 0*d.*, together £85 13*s.* 9*d.* Expenditure on Air Raid Precautions has been met from the Spencer Fund, and therefore appears on both sides of the accounts.

In the financial year 1939–40 we felt the benefit of the ' profit ' on the big Dundee Meeting ; in the year 1940–41 there was again a credit balance—largely because of reduced expenditure (e.g. on salaries), and the Association's restricted activity. Only recently, in the year 1941–42, have we to record an adverse balance. This small deficit may be ascribed to the heavy printing bills, and consequently to the Division's activities. We may reasonably take pride in these activities and rejoice that the deficit on the General Account is no larger. Unless we receive further grants-in-aid during the present financial year, however, we must look forward to a less favourable financial position in 1942–3, but the Council will doubtless feel some satisfaction that as a result of their careful financial policy and foresight during the pre-war years, we have a balance of £1,465 in the Contingency Fund which could be drawn upon in order to meet it, as well as a reserve of £2,000 in the Grants Equalization Fund to meet applications for research grants if the total of the latter should exceed the income from the Caird, Cunningham, Hobson and Leicester Funds. Although I see no reason for excessive optimism, I feel that we have so far weathered the storm much more satisfactorily than I, for one, would have dared to hope in 1939–40.

P. G. H. Boswell.

Balance Sheet,

Corresponding Figures 31st March, 1941. £ s. d.	LIABILITIES	£ s. d.	£ s. d.
	GENERAL PURPOSES :—		
	Sundry Creditors	352 6 10	
	Amounts received in advance for publications	95 18 4	
			448 5 2
	Hon. Sir Charles Parsons' gift (£10,000) and legacy		12,000 0 0
	Sir Alfred Ewing's legacy		500 0 0
	British Science Guild : Capital Fund . .		3,431 9 1
	Accumulated Fund		
	As per last Account	15,795 9 11	
	Less loss on repayment of India 3% Stock .	253 3 6	
			15,542 6 5
	Yarrow Fund		
	As per last Account	3,132 8 0	
	Add Profit on sale of stock	21 8 7	
		3,153 16 7	
	Less Transferred to Income and Expenditure Account under terms of gift . . .	440 10 8	
			2,713 5 11
	Life and Corporation Membership Compositions		
	As per last Account	4,020 19 2	
	Add Received during year :—		
	Life Compositions	110 10 0	
		4,131 9 2	
	Less Transferred to Income and Expenditure Account	40 10 0	
			4,090 19 2
	Grants Equalisation Fund	. . .	2,000 0 0
	Contingency Fund		
	As per last Account	1,469 0 7	
	Less Excess of Expenditure over Income for the year, on General Account . . .	3 12 7	
			1,465 8 0
	Overseas Delegations Fund	. . .	781 3 11
	Secretary's Pension Fund	. . .	2,000 0 0
43,295 16 1			44,972 17 8
	SPECIAL PURPOSES :—		
	Caird Fund		
	Capital as per last Account . . .	9,702 10 2	
	Revenue Account balance as per last Account . . 69 4 9		
	Add Excess of Income over Expenditure for the year . . 174 14 4		
		243 19 1	
9,771 14 11			9,946 9 3
	Mathematical Tables Fund		
	As per last Account	92 4 4	
	Receipts from Sales	39 0 1	
		131 4 5	
	Less Grants paid	10 10 0	
92 4 4			120 14 5
53,159 15 4	Carried forward . . .	55,040 1 4	

31st March, 1942

Corresponding Figures 31st March, 1941. £ s. d.	ASSETS	£ s. d.	£ s. d.
	GENERAL PURPOSES :—		
	Investments as scheduled with Income and Expenditure Account, No. 1	44,009 8 10	
	Sundry debtors and payments in advance	107 18 7	
	Cash at bank	844 14 1	
	Cash in hand	10 16 2	
43,295 16 1			44,972 17 8
	SPECIAL PURPOSES :—		
	Caird Fund Account		
	Investments (see Income and Expenditure Account, No. 2)	9,702 10 2	
	Cash at bank	243 19 1	
9,771 14 11			9,946 9 3
	Mathematical Tables Fund Account		
92 4 4	Cash at bank		120 14 5
53,159 15 4	Carried forward		55,040 1 4

Balance Sheet,

Corresponding Figures 31st March, 1941. £ s. d.	LIABILITIES (*continued*)	£ s. d.	£ s. d.
	Brought forward		55,040 1 4
53,159 15 4	*Cunningham Bequest Fund*		
	As per last Account	1,127 9 4	
	Add Profit on Sale of Stock	55 5 2	
	Add Excess of Income over Expenditure for the year	70 13 5	
1,394 11 10			1,253 7 11
	Toronto University Presentation Fund		
	Capital	178 11 4	
	Revenue Balance as per last Account 8 8 0		
	Less Excess of Expenditure over Income for the year 4 0 6		
		4 7 6	
186 19 4			182 18 10
	Bernard Hobson Fund		
	Capital	1,000 0 0	
	Revenue Balance as per last Account 101 5 4		
	Add Excess of Income over Expenditure for the year 29 14 0		
		130 19 4	
1,101 5 4			1,130 19 4
	Leicester and Leicestershire Fund, 1933		
	Capital	1,000 0 0	
	Revenue Balance as per last Account 14 4 2		
	Add Excess of Income over Expenditure for the year 34 4 2		
		48 8 4	
1,014 4 2			1,048 8 4
	Property Rehabilitation Fund (incorporating balance of the Herbert Spencer Bequest Fund)		
	As per last Account	484 8 9	
	Less Excess of Expenditure over Income for the year	68 11 11	
		415 16 10	
	Creditor	5 1 9	
			420 18 7
518 4 8	*Radford Mather Lecture Fund*		
	Capital	250 0 0	
	Revenue Account : Excess of Income over Expenditure for the year 6 18 1		
	Less Balance overdrawn as per last Account 3 12 2		
		3 5 11	
253 12 2			253 5 11
	Down House		
	Endowment Fund	21,204 17 8	
	Library Fund	10 10 0	
	Suspense Account		
	Balance as per last Account 13 15 5		
	Add Excess of Income over Expenditure for the year 39 13 10		
		53 9 3	
	Creditor	4 5 5	
	Cash Balance overdrawn	35 18 9	
21,296 16 3			21,309 1 1
78,925 9 1			£80,639 1 4

We have examined the foregoing Account with the Books and Vouchers and and the Investments, and the Bank have certified to us that they hold the Deeds

Approved :

EZER GRIFFITHS
R. S. WHIPPLE } *Auditors.*

31st March, 1942 (*continued*)

Corresponding Figures 31st March, 1941.	ASSETS (*continued*)	£ s. d.	£ s. d.
£ s. d.			
53,159 15 4	Brought forward		55,040 1 4
	Cunningham Bequest Fund Account		
	Investments (see Income and Expenditure Account, No. 3)	1,240 12 4	
	Cash at bank	7 15 7	
	Debtor	5 0 0	
1,394 11 10			1,253 7 11
	Toronto University Presentation Fund Account		
	Investments (see Income and Expenditure Account, No. 4)	178 11 4	
	Cash at bank	4 7 6	
186 19 4			182 18 10
	Bernard Hobson Fund Account		
	Investments (see Income and Expenditure Account, No. 5)	1,000 0 0	
	Cash at bank	130 19 4	
1,101 5 4			1,130 19 4
	Leicester and Leicestershire Fund, 1933 Account		
	Investments (see Income and Expenditure Account, No. 6)	1,000 0 0	
	Cash at bank	48 8 4	
1,014 4 2			1,048 8 4
	Property Rehabilitation Fund Account		
	Investments (see Income and Expenditure Account, No. 8)	400 0 0	
	Cash at bank	20 18 7	
518 4 8			420 18 7
	Radford Mather Lecture Fund Account		
	Investments (see Income and Expenditure Account, No. 9)	250 0 0	
	Cash at Bank	3 5 11	
253 12 2			253 5 11
	Down House Account		
	Endowment Fund Investments (see Income and Expenditure Account, No. 7) . .	21,204 17 8	
	Sundry Debtors and Payments in Advance .	91 1 0	
	Cash in hand	13 2 5	
21,296 16 3			21,309 1 1
78,925 9 1			£80,639 1 4

certify the same to be correct. We have also verified the Balance at the Bankers of Down House.

W. B. KEEN & Co., *Chartered Accountants.*
224 Regent Street, London, W. 1.
September 11, 1942.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 1942

No. 1. General Income and Expenditure

Corresponding Figures 31st March, 1941. £ s. d.					£ s. d.	
	Investments :					
	£24,510	0*s.*	2*d.*	Consolidated 2½ per cent. Stock, at cost	18,296 7 6	
	£879	14*s.*	9*d.*	Great Indian Peninsula Railway 'B' Annuity £43, at cost	827 15 0	
	£52	12*s.*	7*d.*	War Stock (Post Office Issue), at cost	54 5 2	
	£8,485	14*s.*	5*d.*	3½ per cent. War Loan Inscribed Stock, at cost	8,541 13 7	
	£6,368	15*s.*	7*d.*	3½ per cent. Conversion Stock, at cost	5,304 8 11	
	£4,184	18*s.*	2*d.*	3 per cent. Local Loans, at cost	3,073 12 2	
	£1,000	0*s.*	0*d.*	4 per cent. Funding Loan	1,170 0 0	
	£100	0*s.*	0*d.*	5 per cent. Great Western Railway Consolidated Pref. Stock	125 0 0	
	£345	16*s.*	8*d.*	3 per cent. London County Consolidated Stock	347 7 6	
	£981	10*s.*	0*d.*	4 per cent. Commonwealth of Australia Stock	1,000 0 0	(Value of
	£5,268	19*s.*	0*d.*	3 per cent. Savings Bonds 1955/65	5,268 19 0	Stocks at
	(Value of Stocks at 31/3/41, £45,833 13s. 7d.)				£44,009 8 10	31/3/42, £49,456 14*s.* 3*d.*)
42,676 14 10						

Cash at bank and in hand, £743 5*s.* 10*d*

	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
25 0 3	To Heat, Lighting and Power	44 17 3	446 5 0	By Annual Membership Subscriptions	393 15 7
4 15 1	,, Stationery	34 15 4		,, Life Compositions : amount transferred	
1 0 0	,, Rent	1 0 0	55 10 0	on expiry of membership	40 10 0
71 11 3	,, Postages	103 16 8		,, Sale of Publications £274 14 0	
7 18 9	,, Travelling Expenses	22 19 5		*Less* Transferred to Mathematical Tables	
84 0 0	,, Audit and Accountancy	31 10 0		Fund 39 0 1	
10 10 0	,, Subscription to Parliamentary and Scientific Committee	10 10 0	60 10 3		235 13 11
71 1 6	,, General Expenses	110 6 4	57 15 8	,, Advertisements in B.A. publications	41 8 8
1,629 3 6	,, Salaries and Wages	1,686 1 0	53 15 8	,, Income Tax recovered	53 5 6

153	*16*	*0*	„ Pension Contributions . . .	79	18	0	*1,458*	*19*	*2*	„ Interest on investments . . .	1,456 6 8
232	*14*	*11*	„ Printing, binding, etc. . . .	372	14	3	*2*	*13*	*2*	„ Interest on current account . .	2 8 3
12	*19*	*9*	„ Norman Lockyer Lecture Expenses .	–	–	–	*15*	*5*	*6*	„ Donations	– – –
9	*4*	*9*	„ Alexander Pedler Lecture Expenses .	–	–	–				„ Rental of Accounting Machine by	
			„ Grants paid to Research Committees				*45*	*1*	*8*	Ministry of Supply . . .	50 0 0
117	*7*	*11*	(see Schedule)	200	0	0	*21*	*5*	*10*	„ Dundee Meeting Excursions . .	– – –
			„ Division for Social and International							„ Air Raid Precautions—amount trans-	
38	*4*	*0*	Relations of Science . . .	137	10	6				ferred from Herbert Spencer Bequest	
			„ Air Raid Precautions at Burlington							(Property Rehabilitation Fund from	
16	*2*	*3*	House	55	15	9	*16*	*2*	*3*	Nov. 1941)	55 15 9
–	–	–	„ War Damage Insurance (Contents) .	18	3	9				„ Yarrow Fund : amount of capital trans-	
–	–	–	„ War Damage Repairs carried out .	8	14	10	*425*	*12*	*10*	ferred†	440 10 8
			„ Balance of Income over Expenditure							„ Donation from American Association	
			for the year transferred to Con-							for the Advancement of Science :	
173	*7*	*1*	tingency Fund	–	–	–				Philadelphia Meeting, towards ex-	
										penses of Division for Social and	
							–	–	–	International Relations . . .	132 13 2
							–	–	–	„ War Damage Claim paid . . .	12 12 4
										„ Balance, being excess of Expenditure	
							–	–	–	over Income for the year . .	3 12 7
2,658	*17*	*0*		£2,918	13	1	*2,658*	*17*	*0*		£2,918 13 1

	Grants authorised, not yet drawn :—	£	s.	d.
– – –	Insular Faunas Committee	10	0	0

† YARROW FUND

The amount shown in the Balance Sheet (p. 264) is the balance of a gift of £10,000 received from Sir Alfred Yarrow in September, 1926, to be used ' as the authorities controlling the Association may think best in the interests of science ', without restriction other than that the capital as well as income must be expended within approximately twenty years.

No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

Corresponding Figures 31st March, 1941. £ s. d.			£ s. d.	
	Investments :			
	£2,627 0*s.* 10*d.*	India 3½ per cent. Stock, at cost	2,400 13 3	
	£2,100 0*s.* 0*d.*	London Midland and Scottish Railway 4 per cent. Preference Stock, at cost	2,190 4 3	
	£2,000 0*s.* 0*d.*	Southern Railway 5 per cent. Preference Stock, at cost	2,594 17 3	
	£2,716 16*s.* 6*d.*	3½ per cent. War Loan Inscribed Stock, at cost	2,516 15 5	(Value at 31/3/42, £9,265 16*s.* 11*d.*)
			£9,702 10 2	
9,702 10 2	(*Value of Stocks at 31/3/41, £8,274 14s. 2d.*)		Cash at bank, £243 19*s.* 1*d.*	

Corresponding Figures 31st March, 1941. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
408 0 0	To Grants paid (see Schedule)	190 0 0	264 1 4	By Dividends and Interest	307 15 4
	,, Balance, being excess of Income over Expenditure for the year	174 14 4	79 14 3	,, Income Tax recovered	56 19 0
			64 4 5	,, Balance, being excess of Expenditure over Income for the year	– – –
408 0 0		£364 14 4	408 0 0		£364 14 4

	Grants authorised, not yet drawn :—	£ s. d.
	Mathematical Tables Committee :	
	for Airy Integral Tables	110 0 0
	for Legendre Function Tables	80 0 0
75 0 0		£190 0 0

No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers ; administered by the Council.

Corresponding Figures 31st March, 1941.						
£ s. d.	*Investments :*			£ s. d.		
	£1,187 6s. 10d.	Consolidated 2½ per cent. Stock		653 0 9		
	£300 0s. 0d.	Port of London 3½ per cent. Stock, 1949/99		216 0 0		
	£737 2s. 10d.	Local Loans 3 per cent. Stock, at cost		371 11 7		(Value at 31/3/42,
1,305 7 2	*(Value of Stocks at 31/3/41, £1,978 5s. 11d.)*			£1,240 12 4		£2,002 16s. 7d.)

Cash at bank, £7 15s. 7d.

Corresponding Figures 31st March, 1941.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941.	INCOME	£ s. d.
£ s. d.			£ s. d.		
150 19 1	To Grants paid (see Schedule)	– – –	61 12 2	By Interest	61 4 3
267 2 6	,, Printing Account for Mathematical Tables	– – –	2 17 8	,, Income Tax recovered	4 9 2
– – –	,, Balance, being excess of Income over Expenditure for the year	70 13 5	– – –	,, Allowance on Printers' account for Vol. ix	5 0 0
			353 11 9	,, Balance, being excess of Expenditure over Income for the year	– – –
418 1 7		£70 13 5	418 1 7		£70 13 5

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

Corresponding Figures 31st March, 1941.					
£ s. d.	*Investment :*				(Value at 31/3/42,
178 11 4	£175 0s. 0d. 3½ per cent. War Stock at cost			£178 11 4	£184 13s. 9d.)
	(Value of Stock at 31/3/41, £182 10s. 0d.)			Cash at bank, £4 7s. 6d.	

Corresponding Figures 31st March, 1941.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941.	INCOME	£ s. d.
£ s. d.			£ s. d.		
2 2 0	To awards	10 3 0	6 2 6	By Interest	6 2 6
4 0 6	,, Balance, being excess of Income over Expenditure for the year	– – –	– – –	,, Balance, being excess of Expenditure over Income for the year	4 0 6
6 2 6		£10 3 0	6 2 6		£10 3 0

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933 ; the income to be applied to the promotion of geological research ; administered by the Council.

Corresponding Figures 31st March, 1941. £ s. d.		£ s. d.	
	Investments :		
	£450 0s. 0d. 4 per cent. Victory Loan at cost	491 13 6	
	£601 9s. 0d. 3 per cent. Local Loans at cost	508 6 6	(Value at 31/3/42,
1,000 0 0	*(Value of Stocks at 31/3/41, £1,085 18s. 3d.)*	£1,000 0 0	£1,091 3s. 0d.)

Cash at bank, £130 19s. 4d.

Corresponding Figures 31st March, 1941. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
12 10 0	To Grants paid (see Schedule) . .	5 0 0	28 8 0	By Interest	27 1 0
	„ Balance, being excess of Income over		6 6 0	„ Income Tax recovered . . .	7 13 0
22 4 0	Expenditure for the year . .	29 14 0			
34 14 0		£34 14 0	34 14 0		£34 14 0

Corresponding Figures 31st March, 1941. £ s. d.	Grants authorised, not yet drawn :—	£ s. d.
30 0 0	Kent's Cavern Committee	5 0 0

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

Corresponding Figures 31st March, 1941. £ s. d.		£
	Investments :	
	£487 2*s.* 11*d.* 3½ per cent. Conversion Stock at cost	500
	£490 5*s.* 11*d.* 3½ per cent. War Stock at cost	500
		(Value at 31/3/42,
1,000 0 0	(*Value of Stocks at 31/3/41, £1,044 18s. 1d.*)	£1,000 £1,035 0*s.* 10*d.*)

Cash at bank, £48 8*s.* 4*d.*

	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
20 0 0	To Grants paid	– – –	34 4 2	By Interest	34 4 2
14 4 2	,, Balance, being excess of Income over Expenditure for the year . .	34 4 2			
34 4 2		£34 4 2	34 4 2		£34 4 2

General Treasurer's Account

No. 7. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (now Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment of £20,000 to the Association as a gift to be held as a memorial to Darwin in custody for the nation.

Corresponding Figures 31st March, 1941. £ s. d.	*Investments :*	£ s. d.	
	DOWN HOUSE ENDOWMENT FUND		
£2,500	Commonwealth of Australia 5 per cent. Stock, 1945/75, at cost	2,468 19 0	
£3,000	Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock, at cost	2,139 17 3	
£2,500	New South Wales 5 per cent. Stock, 1945/65, at cost	2,467 7 9	
£2,500	Western Australia 5 per cent. Stock, 1945/75, at cost	2,472 1 6	
£3,340	Great Western Railway 5 per cent. Consolidated Guaranteed Stock, at cost	3,436 7 5	
£2,500	Birkenhead Railway 4 per cent. Consolidated Stock, at cost	2,013 9 9	(Value of
£7,944 2*s.* 4*d.*	2½ per cent. Consolidated Stock, Inscribed at cost	6,206 15 0	Stocks at 31/3/42,
21,204 17 8		£21,204 17 8	£24,096 6*s.* 5*d.*)
	(Value of Stocks at 31/3/41, £21,928 11s. 9d.)		
	Cash balance overdrawn	£35 18 9	
	Cash in hand	£13 2 5	

Corresponding Figures 31st March, 1941. £ s. d.	EXPENDITURE	£ s. d.
621 15 11	To Wages of Staff	607 16 10
84 4 9	„ Rates, Insurance, etc.	87 5 10
132 0 0	„ Fuel	119 12 3
60 4 8	„ Electricity	54 5 11
26 11 9	„ Drainage Plant	11 15 1

Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
158 2 0	By Rents receivable	234 3 3
261 9 0	„ Income Tax recovered	317 9 6
677 0 6	„ Interest and Dividends	522 9 0
6	„ Sale of Catalogues, Postcards and Photographs	5 6

16	18	5	„ Water			19	15	9	
20	12	6	„ Installation of Electric Mains			–	–	–	
51	18	3	„ Repairs and Renewals			13	12	2	
22	7	2	„ Land and Garden: Materials and Maintenance			26	16	3	
5	5	0	„ Donations to Village Institutions			5	5	0	
22	17	10	„ Household Requisites, etc.			11	6	10	
	6	11	„ Transport and Carriage			–	–	–	
7	7	10	„ Printing, Postages, Telephone, and Stationery			9	11	6	
104	0	6	„ Air Raid Precautions			23	17	1	
–	–	–	„ War Damage Insurance (Contents)			67	10	0	
5	9	0	„ War Damage			–	–	–	
63	2	0	„ Balance, being excess of Income over Expenditure for the year transferred to Suspense Account			39	13	10	
1,245	2	6			£	1,098	4	4	

			By Grant from Herbert Spencer Bequest :—						
20	12	6	Towards Electric Mains			–	–	–	
104	0	6	Towards Air Raid Precautions			23	17	1	
124	13	0	By Sale of Electric Lighting Plant, less Commission on Sale			–	–	–	
23	17	6							
1,245	2	6			£	1,098	4	4	

Note.—At the 31st March 1942 there was a liability in respect of War Damage Insurance on Down House, the amount of which has not yet been ascertained.

No. 8. Property Rehabilitation Fund (incorporating balance of the Herbert Spencer Bequest Fund)

Corresponding Figures 31st March, 1941. £ s. d.		£ s. d.	
	Investments :		
	£398 4*s.* 3*d.* 3 per cent. London County Consolidated Stock, 1956/61, at cost . .	400 0 0	
			(Value at 31/3/42,
400 0 0	(*Value of Stocks at 31/3/41, £381 5s. 5d.*)	£400 0 0	£398 4*s.* 3*d.*)

Cash at bank, £20 18*s.* 7*d.*

Corresponding Figures 31st March, 1941. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
	To Down House—Installation of Electric		13 15 8	By Interest	5 19 5
20 12 6	Mains	– – –	4 3 6	„ Income Tax recovered . . .	5 1 6
104 0 6	„ Air Raid Precautions at Down House	23 17 1		„ Balance, being excess of Expenditure	
	„ Air Raid Precautions at Burlington		122 16 1	over Income for the year . .	68 11 11
16 2 3	House	55 15 9			
140 15 3		£79 12 10	140 15 3		£79 12 10

No. 9. Radford Mather Lecture Fund

A gift of £250 received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting the expense of triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.

Corresponding Figures 31st March, 1941. £ s. d.	*Investment :*	£ s. d.	(Value at)
250 0 0	£248 17*s.* 8*d.* 3 per cent. London County Consolidated Stock, 1956/61, at cost . .	250 0 0	31/3/42,
	(*Value of Stock at 31/3/41, £238 18s. 6d.*)		£248 17*s.* 8*d.*)
		Cash at bank, £3 5*s.* 11*d.*	

Corresponding Figures 31st March, 1941. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1941. £ s. d.	INCOME	£ s. d.
21 0 0	To Lecture Fee	– – –	4 5 10	By Interest	3 14 8
3 14 0	,, Expenses of Lecture	– – –	2 12 3	,, Income Tax recovered . . .	3 3 5
– – –	,, Balance, being Income for the year .	6 18 1		,, *Balance, being excess of Expenditure over*	
			17 15 11	*Income for the year*	– – –
24 14 0		£6 18 1	24 14 0		£6 18 1

Schedule of Grants paid to Research Committees, etc.

during the financial year to March 31, 1942

NOTE.—The year indicated in brackets after the title of each committee is that of its original appointment, and the sum, if any, is that previously expended out of grants by the Association.

	£ s. d.	£ s. d.
1. Paid out of the General Fund.		
Zoological Record (1923 : £835) (*See Caird Fund*)	50 0 0	
Plymouth Laboratory (1886 : £1,548 10*s.* 8*d.*)	50 0 0	
Freshwater Biological Station (1930 : £787 15*s.* 11*d.*)	75 0 0	
Algae and Protozoa (1939 : £50)	25 0 0	
		200 0 0
2. Paid out of Caird Fund.		
Seismology (1895 : £5,020 14*s.* 8*d.*)	100 0 0	
Bird Behaviour (1938 : £40)	40 0 0	
Zoological Record (*see General Fund*)	50 0 0	
		190 0 0
3. Paid out of Cunningham Bequest (1929).		
Mathematical Tables †		267 2 6
4. Paid out of Leicester and Leicestershire Fund, 1933.		– – –
5. Paid out of the Bernard Hobson Fund.		
Kent's Cavern (1925 : £70)		5 0 0
6. Paid out of Mathematical Tables Fund.		
Mathematical Tables †		10 10 0
		£672 12 6

† Mathematical Tables Committee.

	£ s. d.	£ s. d.
Total grants paid to March 31, 1942 :—		
From Cunningham Bequest Fund		2,835 18 11
„ Caird Fund		1,292 8 2
„ Mathematical Tables Fund		176 10 0
„ General Fund		415 17 6
„ Royal Society grant (1933)		50 0 0
		£4,770 14 7
Amount recovered by sale of tables	424 8 5	
„ „ „ hire of accounting machine by Ministry of Supply	95 1 8	
		519 10 1
		£4,251 4 6

'THE ADVANCEMENT OF SCIENCE'

In the previous issue of *The Advancement of Science* (vol. ii, no. 6, p. 184, July 1942) a report of the principal activities of the Association was provided under the heading 'Current Proceedings.' In the present issue there is no need to repeat this heading, since the annual Report of the Council to the General Committee and the General Treasurer's Statement and Account in preceding pages together provide a full review of the Association's work and finances. The Council's report, dated September 2, may, however, be supplemented in respect of the Committee on Mineral Resources, which, in response to the resolution from the Conference reported on pages 253 and 261, has now been constituted under the chairmanship of Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S., with Dr. C. H. Desch, F.R.S., as vice-chairman. Its terms of reference are: To inquire into, and report upon, the state of knowledge of mineral resources, other than coal and petroleum, essential for modern industrial development, from the point of view of the Fourth Clause of the Atlantic Charter.

It may be appropriate here to review the functions and contents of this publication, *The Advancement of Science*, which has not long been in existence, so that there may well be readers of the present issue who are unacquainted with previous numbers. These are still procurable at the price of 5*s*. per copy from the British Association, Burlington House, London, W. 1, or from any bookseller. *There is a subscription rate of 15s. for four parts, and readers interested in this form of subscription, whose numbers it is desired to increase, should communicate with the above address, enclosing remittance.* There are also terms of membership of the Association which entitle members to receive publications without further charge. Information as to these terms may be obtained on application.

The Advancement of Science was inaugurated as the official publication of the Association in October, 1939. It superseded an annual volume of reports, which had appeared without intermission since the foundation of the Association in 1831. A form of publication maintained for so many years was not lightly to be abolished, but its disadvantages had long been manifest. In place of an annual and rather cumbersome volume, *The Advancement of Science* was designed as a quarterly, and the first four numbers, constituting Volume I, appeared as such, so that the Association's practice of producing an annual volume was not wholly rejected.

The main function of the new publication continued to be that of reporting the transactions of the Association's great annual meeting, but it was also designed to keep members and other readers informed of the current activities of the Association in a manner more closely up to date than had been possible before. The first four numbers, which appeared in October 1939, January, April, and July 1940, contained in the main transactions of the annual meeting in the former year, which was opened at Dundee at the end of August. That meeting was brought to a premature close by the imminent declaration of war, but a large number of the addresses and other communications which would otherwise have occupied its latter part, but had to remain unspoken, were nevertheless published. The first four numbers of *The Advancement of Science*, therefore, cover the whole *intended* field of the Dundee Meeting.

During the first few months of the war the normal work of the Association was in great measure in suspense. It was clearly impossible to arrange annual meetings on the peacetime scale. The publication of *The Advancement of Science* temporarily ceased. But soon there appeared a new outlet for the Association's activity. Its Division for the Social and International Relations of Science, which is competent to convene its own conferences, did so in September 1941 when the now famous Conference on Science and World Order was held. This has been followed by the Conferences on European Agriculture and Mineral Resources and the Atlantic Charter—special subjects on which the need for discussion had been indicated by the preceding more general conference.

The transactions of these conferences have been published in *The Advancement of Science*; and for the benefit of readers of this number who would wish to follow the earlier proceedings in this field, the contents of Nos. 5 and 6 are subjoined.

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